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Final Report

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Universal Stowage Module for Future Space Exploration

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FINAL REPORT

UNIVERSAL STOWAGE MODULE FOR FUTURE SPACE EXPLORATION

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FOREWORD

This final report describes the design of the Universal Stowage Module that is intended for use on Shuttle payloads. This document presents the results of work performed by the Martin Marietta Corporation's Denver Division for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center. The final report was prepared as partial fulfillment of Contract NAS8-29777, Universal Stowage Module for Future Space Exploration. The NASA Technical Monitor was Mr. Paul Artis, of the Astronautics Laboratory, Mechanical and Crew Systems Integration Division.

ABSTRACT

This final report describes the design effort accomplished under contract NAS8-29777 to develop, design, and fabricate a prototype Universal Stowage Module with universal restraints that are readily adaptable for most sizes and shapes of items that would be launched into space and returned aboard shuttle payloads.

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I. INTRODUCTION

The objective of this contract was to develop, design, and fabricate a prototype stowage module, with internal restraints, that can be used for stowage of any of the items that are normally launched to support a space mission. These items could be of any size or shape and would typically include food experiment hardware, consumables, food, clothing, tools, etc. The universal stowage module is intended for use on shuttle payloads and future space missions.

The current designs for stowage lockers are not suitable for universal stowage. Several different locker configurations were supplied for the Skylab program, and many of them were one-of-a-kind designs specifically designed to stow experiment hardware. The other lockers required special mounting provisions, filler materials, and peculiar vibration isolation configurations. The majority of the lockers were not removable from the vehicle and thus the equipment had to be loaded on the vehicle, rather than in the locker, prior to launch. It was also difficult to change the contents, and the locker nomenclature, just prior to launch.

The lockers were not symmetrical in their dimensions, were of different sizes and shapes, had different load capacities, exhibited various external mounting provisions, and did not lend themselves to a consistent simple method of defining interface criteria. In addition, the mounting hardware and fasteners were not designed for commonality.

The universal stowage module described in this report corrects the problems experienced on past missions. The primary design criteria was that the stowage module be universal in accommodating most sizes and shapes of items that would be launched and returned in a shuttle payload, and that it withstand the vibration criteria and loads imposed during launch, and upon return to earth.

This report describes the design criteria, design analysis, the rational used in the design of the Universal Stowage Module.

II. DESIGN CRITERIA

The design, environmental, and material criteria listed in the contract are shown in sections A, C, and D. Design guidelines that are desirable to satisfy the design intent of the stowage modules are listed in section B.

The basic intent of the design is to provide a stowage locker that can be loaded by an experiment investigator or contract supplier at some remote location. The locker could then be shipped to the launch site, and installed into the shuttle in either a horizontal or vertical configuration. It is desirable that the design accommodate last minute changes prior to launch in either the contents, module nomenclature, or module location. When on-orbit--the module, module drawers, or contents can be removed and transported to another location within the shuttle payload. Drawers, dividers, and nomenclature are interchangable between modules.

The module is designed so that human factors design is maximized whenever possible with attention to rounded edges, captive fasteners, commonality, minimum motion and crew effort, tool requirements, etc. The interior dimensions can be revised to the optimum dimensions when the shuttle crew compartment and the shuttle payload interior are better defined.

A. DESIGN CRITERIA

1. Provide a Universal Module that will accommodate most sizes and shapes of items that possibly would be launched into space and returned (within the limits of the interior volume and shape of the stowage compartment).

2. Reduce interface control documentation.

3. Must withstand the launch and operating environment described in the statement of work.

4. The interior dimensions of the stowage module shall be .607 meter x .607 meter x .607 meter (2 feet x 2 feet x 2 feet).

5. The maximum weight of the contents stored in the module will not exceed 36.3 kilograms (80 pounds).

6. The maximum density of the module contents shall be 416 kilograms per cubic meter (26 pounds per cubic feet).

7. The maximum allowable empty weight of the module shall be 31.7 kilograms (70 pounds).

8. Provide adequate restraints within the locker so that a wide variety of items may be secured.

9. Design for ease of operation for loading and unloading in 1-G and zero-g environment.

B. DESIGN GUIDELINES

1. The module design should facilitate loading at a remote location with later installation in the spacecraft in a horizontal or vertical position.

2. The Skylab stowage list shall be considered as being representative of the type hardware that will be stowed in the universal stowage module.

3. The restraint system and module design should accommodate last minute changes prior to launch.

4. The module size should be such that it can be transported thru a one meter diameter hatch by one crew member in a zero-g environment.

5. Design so that the locker (or portion of the locker) can be removed from its mount and transported to other areas of the spacecraft in zero-g.

6. The basic spacecraft may be defined as a shuttle payload that is cylindrical in shape with docking port(s) on the end(s). The maximum diameter shall be 15 feet.

C. ENVIRONMENTAL CRITERIA

1.0 Launch and Reentry Loads

1.1 Vibration

1.1.1 Sinsusoidal Vehicle Dynamics Environment - The component shall withstand the following environment. Logarithmic sweep at the rate of 3.0 octaves/minute from the low frequency to the high frequency in the thrust direction, 3 Hz to 60 Hz (4.3 octaves).

3 - 7 Hz at 0.43 inch D. A. Disp.
7 - 14 Hz at 1.1 g peak
14 - 25 Hz at 0.11 inch D. A. Disp.
25 - 60 Hz at 3.6 g peak

The component shall withstand the following environment. Logarithmic sweep at the rate of 3.0 octaves/minute from the low frequency to the high frequency in the radial and tangential directions, 2 Hz to 20 Hz (3.3 octaves).

2 - 4 Hz at 0.34 inch D. A. Disp.
4 - 7 Hz 0.28 g peak
7 - 20 Hz 0.08 g peak

1.1.2 Sinusoidal Vibration Evaluation - The component will be subjected to the following excitation. Logarithmic sweep at the rate of 1.0 octave/minute from the low frequency to the high frequency in three mutually perpendicular directions. 20 Hz to 2,000 Hz (6-2/3 octaves).

20 - 100 Hz at 0.002 inches D. A. Disp.
100 - 2000 Hz at 1 g peak

1.1.3 Random Vibration Environment - The component will withstand the specified random vibration for 1.0 minute in each of the three mutually perpendicular directions. The excitation will be applied as one input over the frequency interval from 20 to 2,000 Hz.

20 - 100 Hz at +9 dB/octave
100 - 250 Hz at $1g^2$/Hz
250 - 2000 Hz at -6 dB/octave

2.0 Steady State Load Factors

2.1 Orbiter Payload Load Factors

Structure Load Factors (Max G)

Direction	Steady State	Design Limit	Crash
X-Axis	+3.0, -1.0	± 4.5	-8.0, +1.5
Y-Axis	+1.0	± 2.0	+1.5
Z-Axis	+1.0	± 3.0	+4.5, -2.0

2.2 Operating Temperature

The minimum operating temperature will be 50°F.
The maximum operating temperature will be 90°F.

2.3 Operating Atmosphere

The atmosphere during operation will be approximately eighty (80) per cent nitrogen and approximately twenty (20) per cent oxygen. The pressure will be 14.7 psia.

2.4 Humidity

The operating range of the relative humidity will be thirty (30) per cent minimum and ninety-five (95) per cent maximum.

D. MATERIAL SELECTION CRITERIA

1.0 Control of material for flammability can be achieved through the use of an existing standard developed for this purpose by the Federal Aviation Administration, Publication FAR 25, Airworthiness Standard, and actively maintained to the state-of-the-art. This specification provides the requirements of fire safe aircraft for all commercial passenger travel by U. S. carriers. As such, it provides for the use and control of materials in a vehicle/craft operating in a nominal earth atmosphere.

2.0 Odor and outgassing are still part of the hazards of a closed system, unlike earthbound aircraft, and require the same rigid control now exercised for current spacecraft. Some relief is realized in the increase in atmospheric pressure as the outgassing and attendant odors will generally be less severe. While this would make more materials available, it does not modify the levels of contaminants that are acceptable and the need for matching vehicle system scrubbing capabilities to contaminant contributions. For control of odor and outgassing, MSFC-SPEC-101B modified, would be applicable.

3.0 Requirements for control of nometallic materials for odor and offgassing will be in accordance with applicable portions of MSFC-SPEC-101B, inhabited area, with the following modifications:

3.1 The classification of materials by type for usage locations and applications (paragraphs 1.2.2, 3.2.2.1 and subs, and Table 1) is not required.

3.2 The material control plan submitted is waived.

3.3 Batch lot testing (paragraph 3.2.1) is not required.

3.4 Test No. 9 is applicable but will be conducted by the Government as required.

4.0 Requirements for nonmetallic material flammability control will be in accordance with applicable portions of Federal Aviation Regulation Volume III transmittal Part 25 with the following modifications:

Applicable Section:

Fire Protection

Modifications:

Burning drippings or spatter (paragraph 25.853 (a, b)) from the test specimen during or after removal of the flame is not permitted.

III. DESIGN DESCRIPTION

A. UNIVERSAL STOWAGE MODULE

The basic module, Fig. III-1, has interior dimensions of .607 meter x .607 meter x .607 meter (24 x 24 x 24 inches) with smooth flat surfaces on all of the interior surfaces. The primary restraining concept of the module is a grid of calfax fastener receptacles on each wall of the module whereby equipment, dividers, tie-down devices, and drawer systems can be mounted.

Each wall panel has a grid of 65 calfax fastener receptacles spaced on 5 centimeter (2 inch) centers around the edge of each panel, and at 10.16 centimeter (4 inch) centerlines in the center portion of the panel. The design is such that the calfax fastener grid can be expanded to a 5 centimeter (2 inch) grid to achieve maximum utilization. The calfax fastener used here is the same as that used on the Skylab missions, which proved to be highly successful in actual mission use. The calfax fastener requires 1-1/2 turns for total engagement.

The module panels are constructed from 2024-T3 aluminum that has been anodized for protection against corrosion. The panel construction consists of two panels; the outer panel is a beaded panel with ten beads on 5 centimeter (2 inch) centers, and it is spot welded to an inner panel that provides added strength and a smooth inside surface on the module walls and back panel. The smooth inside walls provide a flat surface for maximum load carrying capability, and also simplifies the interface documentation. The smooth surfaces and flush corners lend themselves to better cleaning and contamination control.

The two module doors swing out from the center of the module to allow full and clear access to the module contents. Either door can be opened as desired, and do not require one door to be opened before the other. The same proven door latches as was used on the Skylab lockers are being used here. With this type latch, the doors can be opened or closed (slammed) with a one-handed operation. Each door has its individual lock. The door hinges are tension loaded so that they will stay positioned in zero-g. The tension can be adjusted for any wear that may take place in the hinge.

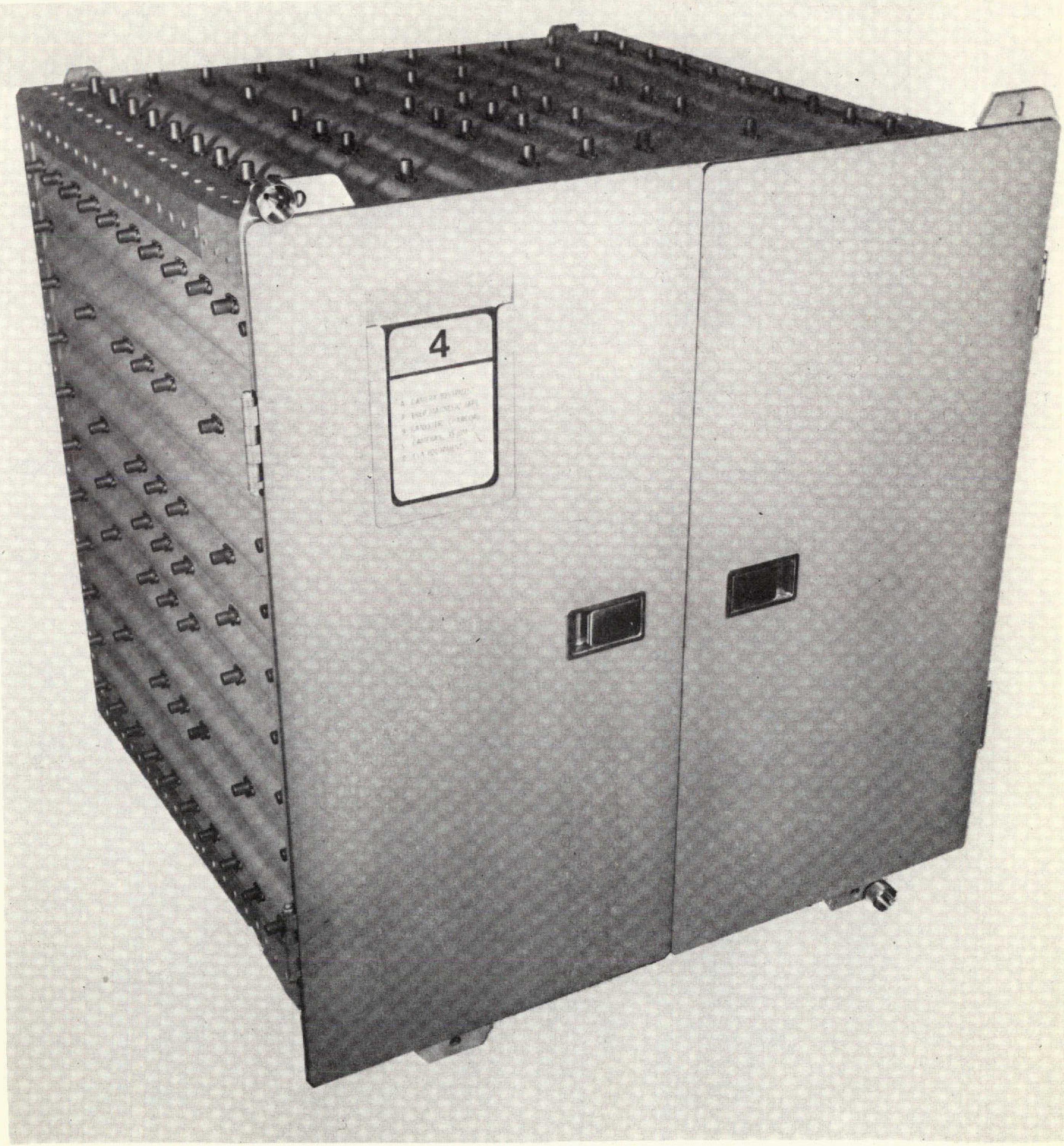


FIGURE III-1 UNIVERSAL STOWAGE MODULE

a nomenclature card, Figure III-1, is positioned on the left hand door, in the upper left hand corner. Each module will have its individual module number, and the nomenclature card will be color coded as to the general category of equipment being stowed in the module. The nomenclature card is designed so that the information can be easily typed on the card, and revised just prior to launch. In flight, the card could be reversed in its holder and the revised information written in with a felt tip pen. The nomenclature card is recessed flush with the door to prevent damage to the card or card holder.

The nomenclature card on the outside of the module lists the stowage module number, the general category of equipment inside the module, and its location. Location is broadly categorized by the respective quadrant inside the module; using the letters A, B, C, D to define the upper left hand quadrant (A), upper right hand (B) lower left hand (c), and lower right hand quadrant (D) as shown in Figure III-2. A more defined level of detail is presented for those items that are hidden from view such as in the drawers.

B. SPACECRAFT INSTALLATION

One method of installing the universal module in the shuttle payload is shown in Figure III-3. Although it is not a requirement of this contract to design or supply the spacecraft installation system, the method of installation does affect and is an integral part of the stowage module design.

Figure III-3 shows a "jungle-gym" approach to mounting the stowage modules. The module is guided in on teflon guide rails to that the guide pins (.65 centimeters, 1/4 inch) engage the rear flange of the stowage module, which in turn, take out launch loads. The take-up wedge at the front of the module aligns the front flange, and four .96 centimeters (3/8 inch) bolts are used to take out the loads at the front flange. The four mounting tabs on the front flange serve to orientate the module so that it can only be installed in one orientation for launch. The mounting tabs are alternately spaced so that they will nest inside each other in the jungle-gym, thus taking up less dead space and providing a more efficient utilization of space. The two calfax fasteners are used to temporarily hold in the module during zero-g operations when the module is being moved from the launch position to other use locations within the spacecraft.

The guide rails, Figure III-4, are tapered from front to back so that the module can be easily positioned in the "jungle-gym" system. Approximately 1.27 centimeters (1/2 inch) of take-up provided from front to back.

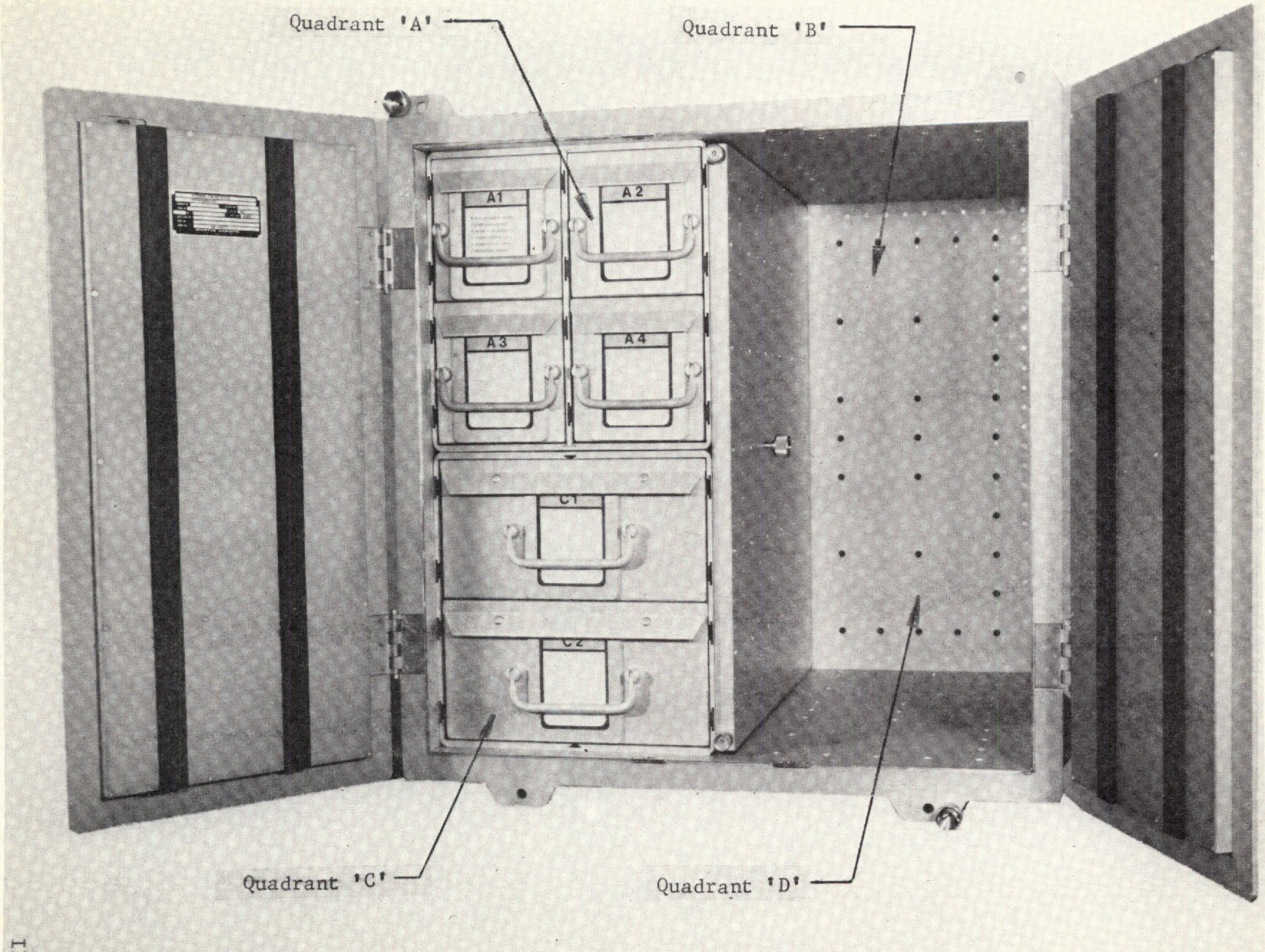
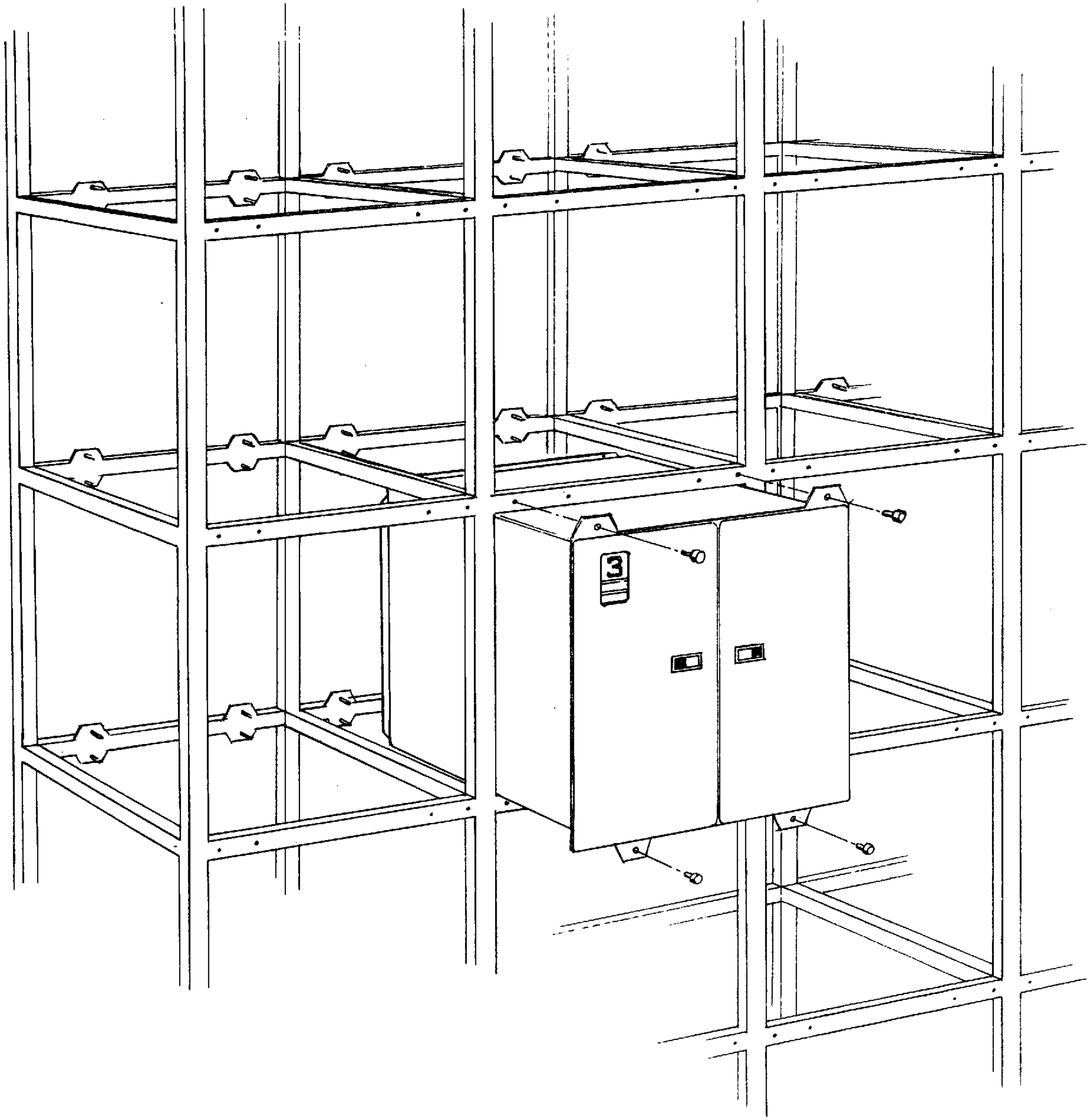
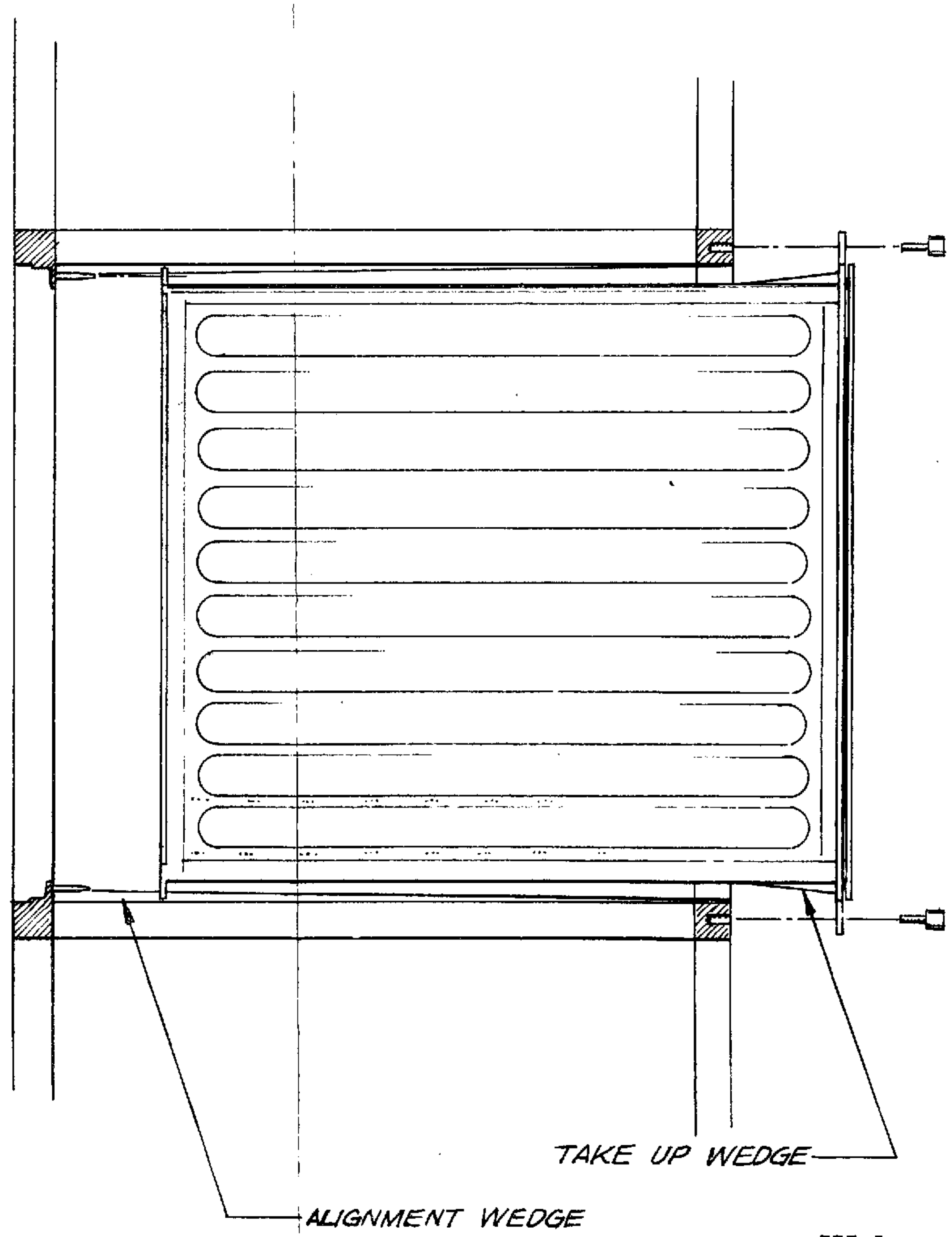


FIGURE III-2 UNIVERSAL STOWAGE MODULE - INTERIOR VIEW

FIGURE III-3 SPACECRAFT INSTALLATION





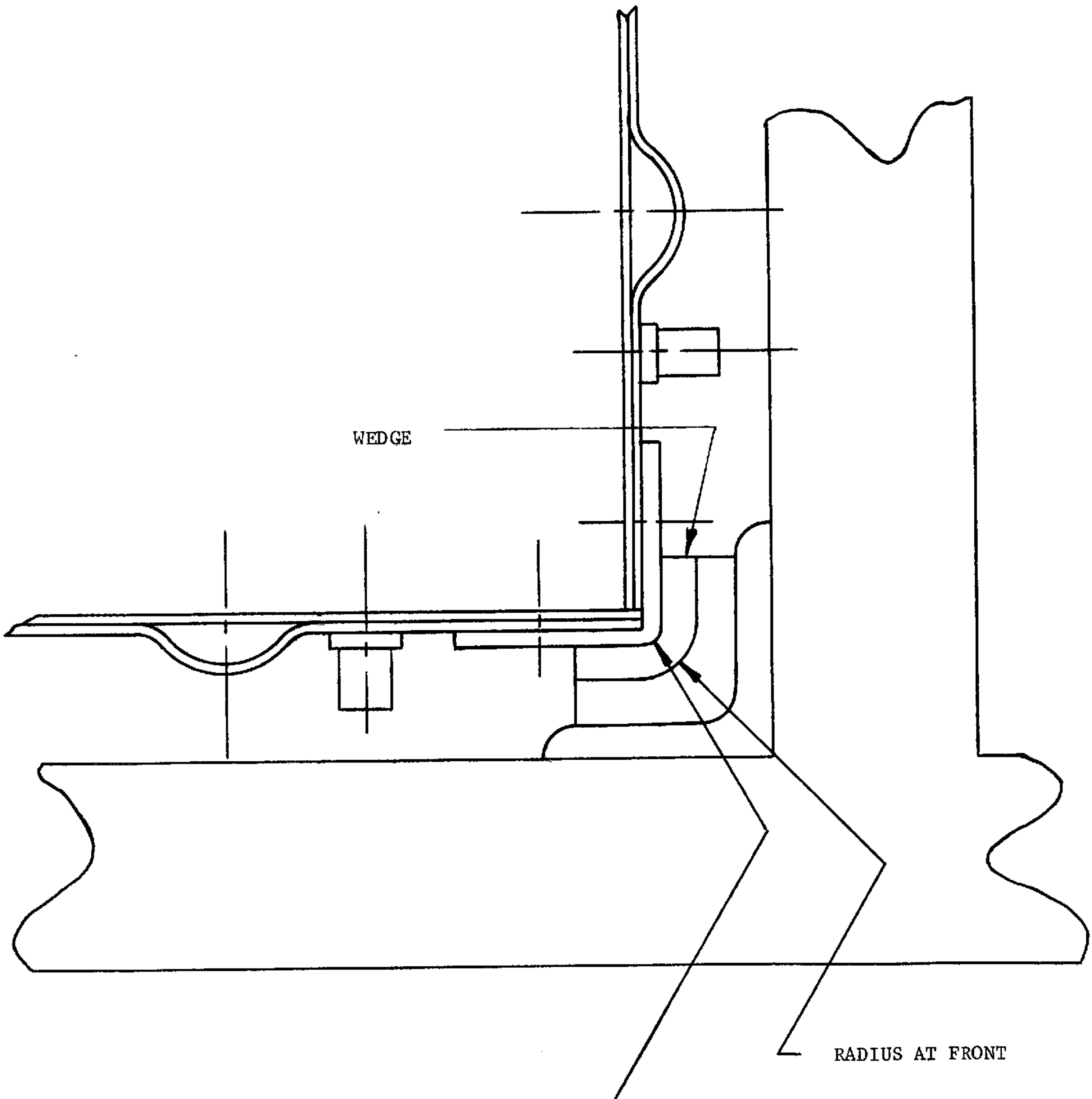


FIGURE III-4 GUIDE RAIL SYSTEM

C. CENTRAL DIVIDER

The central divider, Figure III-5, is used to divide the total module into subsections, to provide two more surfaces for mounting equipment, and as a structural member to fasten the drawer divider to.

The central divider has a grid of calfax fastener receptacles on each surface spaced on 10.16 centimeter (4 inch) centers. This grid can be used for mounting equipment or subsection dividers such as the drawer divider system.

Two tee-section guide rails are mounted to the module walls with countersunk calfax studs, and the divider is guided into position by these rails. The divider can be mounted in either the horizontal or vertical position. A total of fourteen positions are available for mounting the divider. The divider has two calfax fasteners that fix the divider to the guide rails and prevent failure during vibration. Two guide pins at the rear of the module also take out launch loads.

D. DRAWER SYSTEM

A drawer system is part of the basic concept in universal stowage. The drawers, Figure III-6, have a guide rail system for smooth operation and to restrain the drawers during launch vibration. The male portion of the guide rail on the drawer is of the same cross section as the Skylab "universal mount" and thus the drawer can be removed from the module, as in the case of a tool drawer, and restained while at the work station.

The drawer divider system, Figure III-7, provides a suspension system for the drawers. The drawers may be mounted in any or all of the four quadrants in the module.

The drawer design is similar to a safety deposit box such that the lid can be opered without having to remove the drawer, Figure III-8. Each drawer handle is detented so that it will stay in the desired position. The drawer lid is also detented so that it will stay closed during transportation. The front edge of the lid protrudes out as a lip for opening the lid.

Two different sizes of drawers are provided with the module. The small drawers measure 57.62 cm long x 14.35 cm high x 13.60 cm wide (22.7 x 5.6 x 5.4 inches) and the large drawers are the same length and height, but are 28.16 cm wide (11.1 inches).

Four of the drawers exhibit interior packaging concepts. One drawer has a divider system so that the interior volume of the drawer can be divided into 1.27 centimeter (1/2 inch) increments. One drawer is fully lined with mosite foam rubber to show vibration protection. Bubblepack protection and soft cloth wrapping are exhibited in the other two drawers.

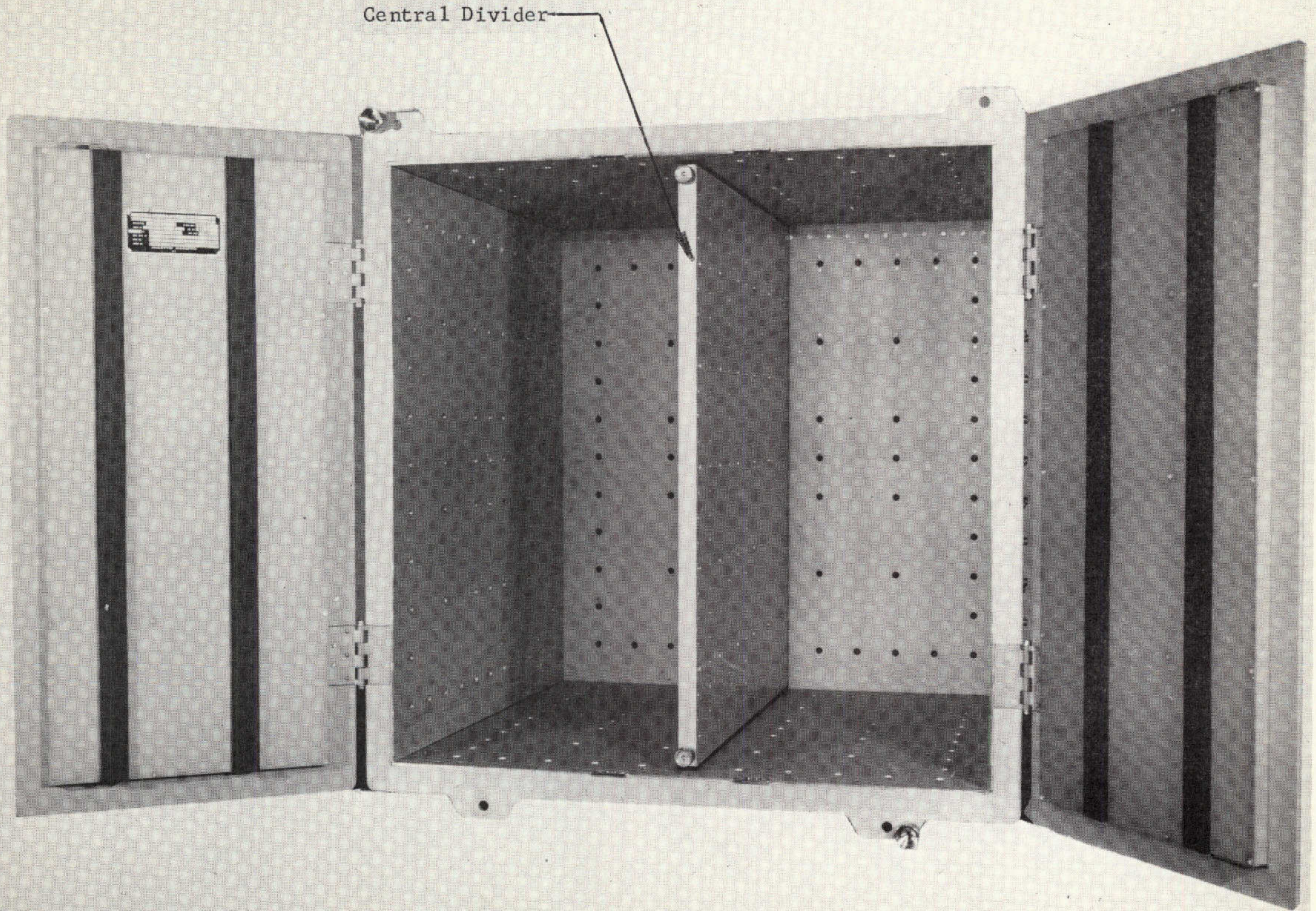


FIGURE III-5 CENTRAL DIVIDER

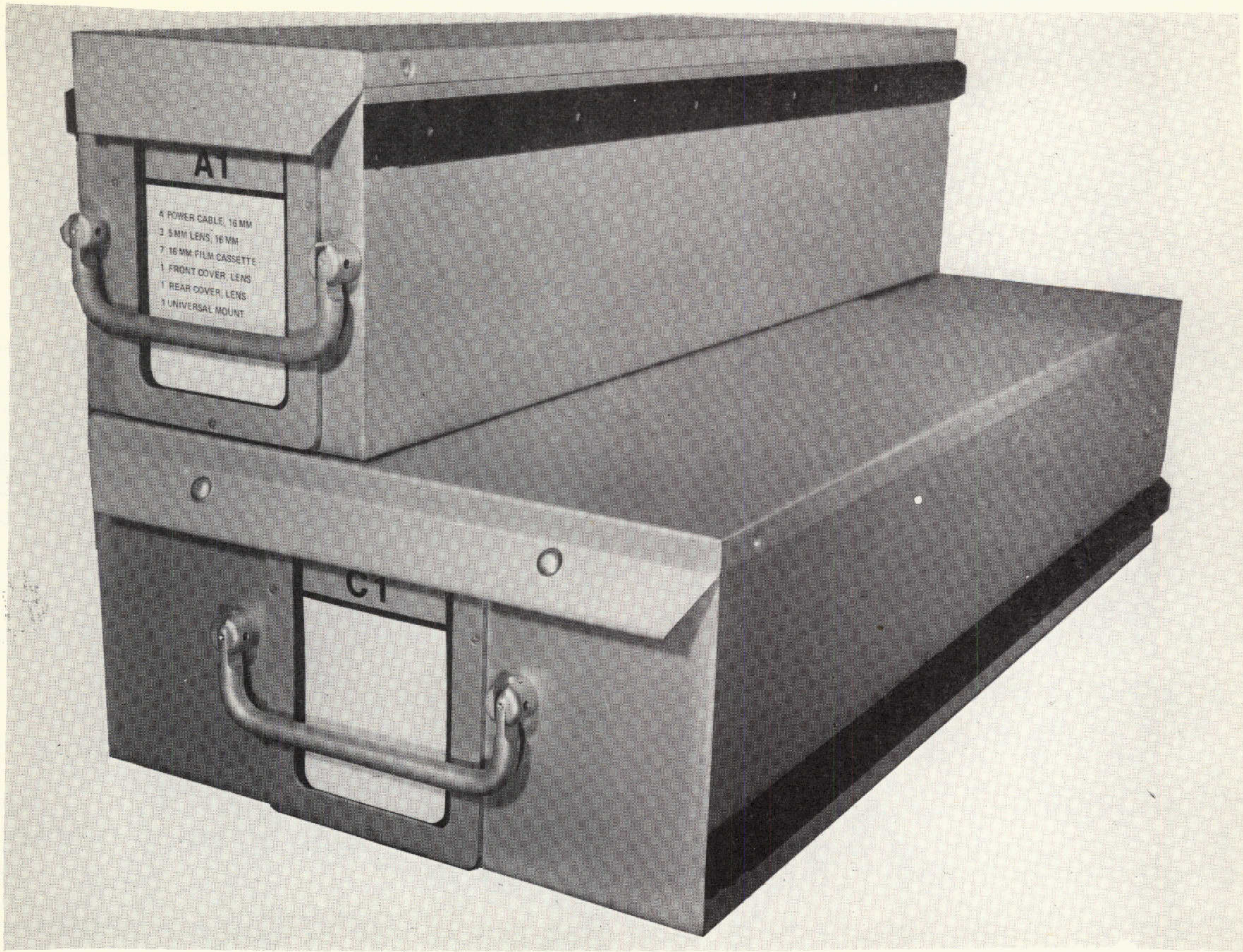


FIGURE III-6 DRAWERS

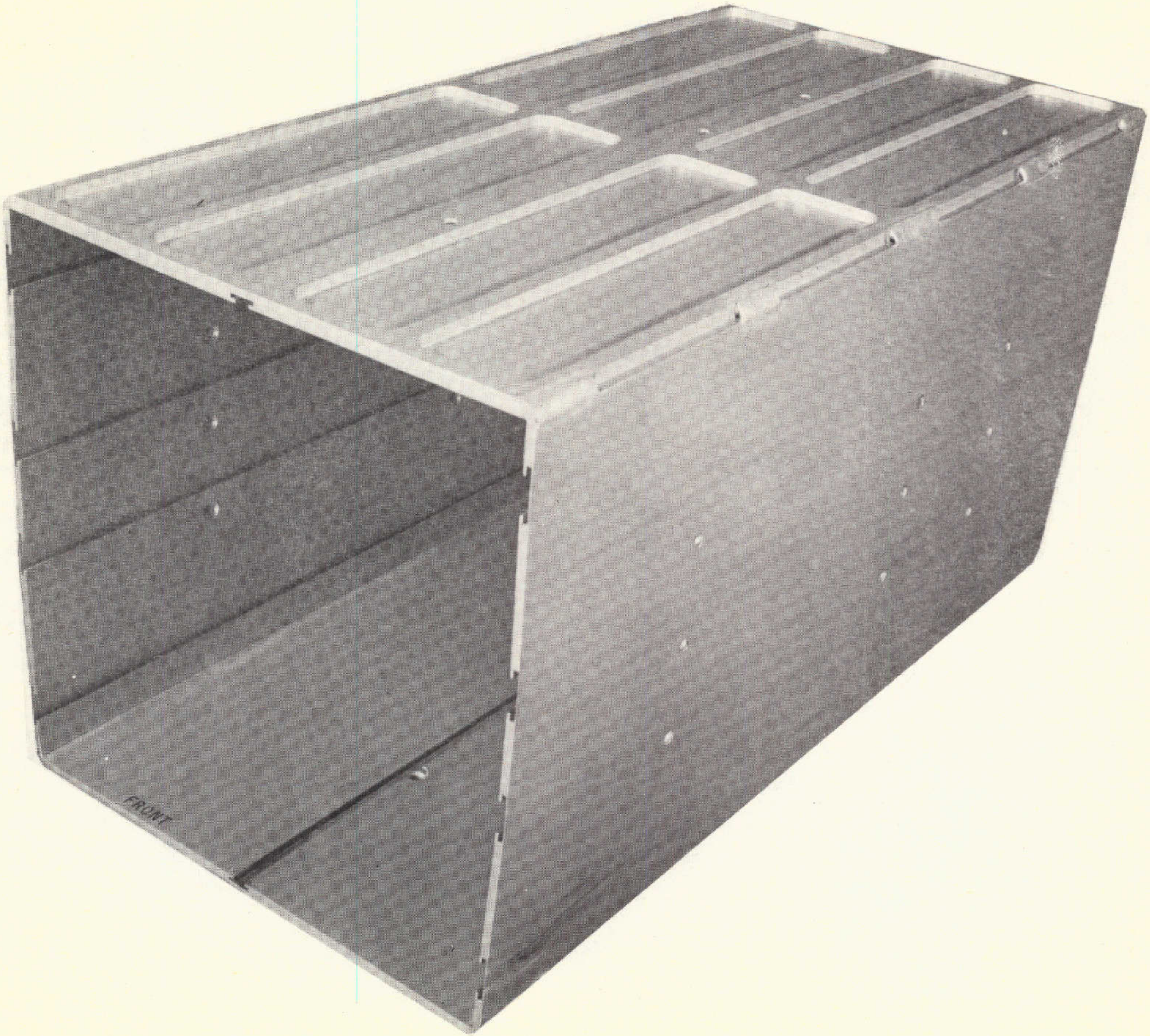


FIGURE III-7 DRAWER DIVIDER SYSTEM

The drawer suspension system is modularized into 1/4 sections so that any combination of 1/4 section drawers (both horizontal and vertical) can be used in the universal stowage module. In addition, the drawer guides are designed such that in zero-g the drawers can be reorganized into another stowage module. The drawers are held in place during launch (front to back movement) by foam rubber pads which bear against the door.

A nomenclature card is mounted on the front of each drawer, Figure III-8, which gives a detailed listing of the drawing contents, and also the quantity of each item. The numerical designation (A1) cooresponds to the quandrant, and sub-quadrant, in which the drawer is located. The nomenclature cards are removable and list of contents can be typed on with a typewriter.

E. UNIVERSAL TIE-DOWN DEVICE

The universal tie-down, Figure III-9, is a ratchet type device with a flexible cloth band that can be used to hold down large objects such as a CO_2 canister. The system consists of a ratchet take-up, the flexible cloth band, and an anchor. The cloth band is simply looped over the equipment to be restrained and hooked into the anchor, then the ratchet device takes up the tension in the band. Figure III-10 shows the techniques that can be used to hold down equipment. The flexible band is 243.8 centimeters long (8 feet) with anchor stops at 30.5 centimeter (1 foot) intervals. The 243 cm band will accept the largest object that can be mounted within the confines of the module. The anchor stops on the band provide a universal band length so that it will accept any size object, or objects.

The universal tie-down can also be used as a general purpose device, or an "astronaut vise", to hold down objects while performing maintenance tasks in Space. The tie-down device exerts considerable force for this purpose and also the band provides a flexible soft surface which will conform to different shaped items without marring its surface.

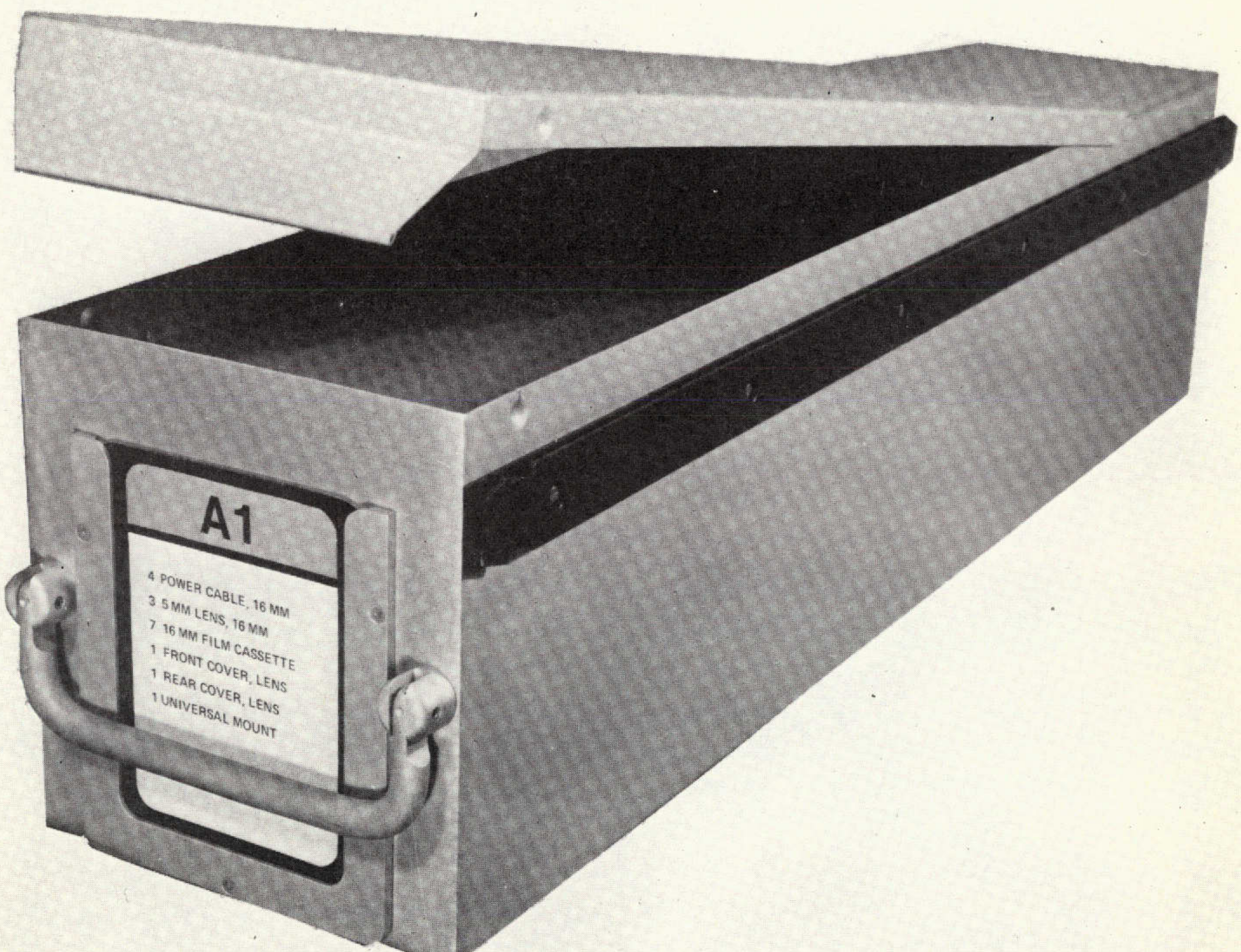


FIGURE III-8   SMALL DRAWER

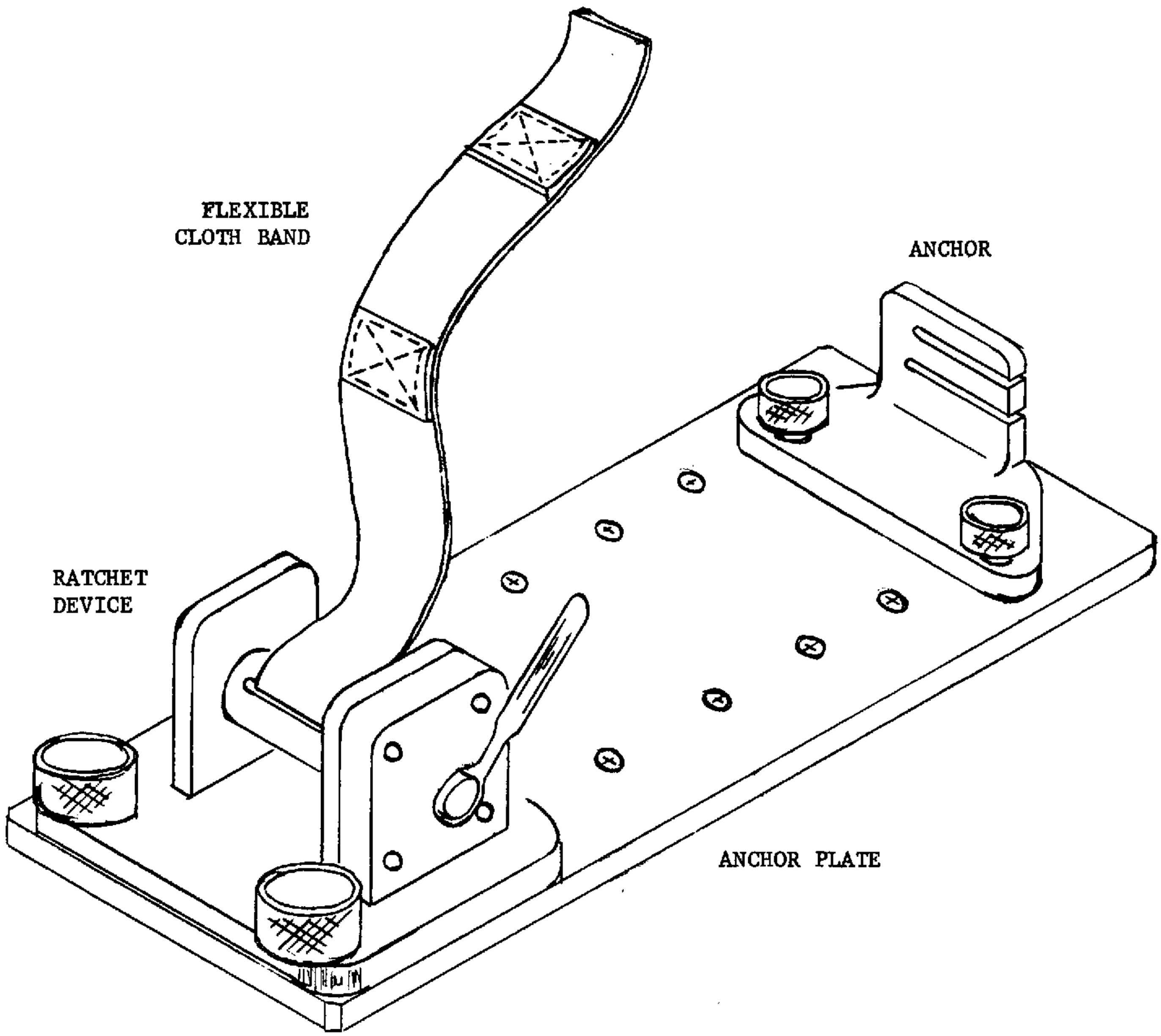
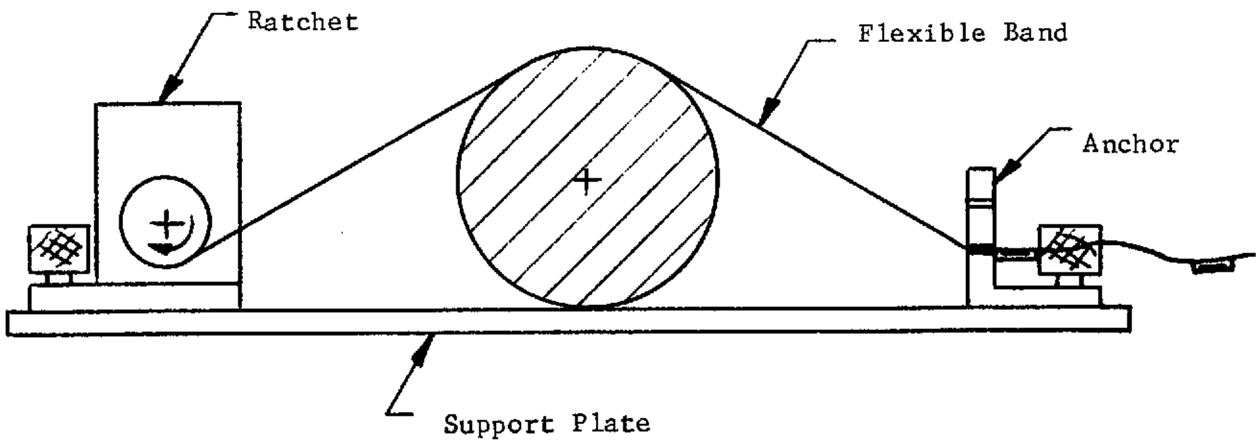
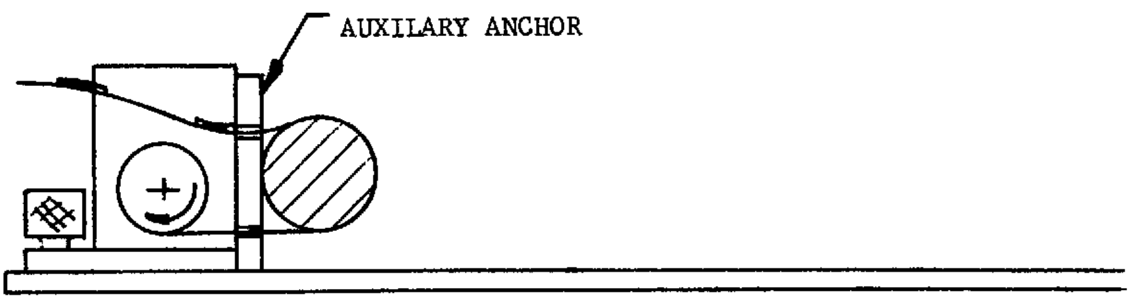
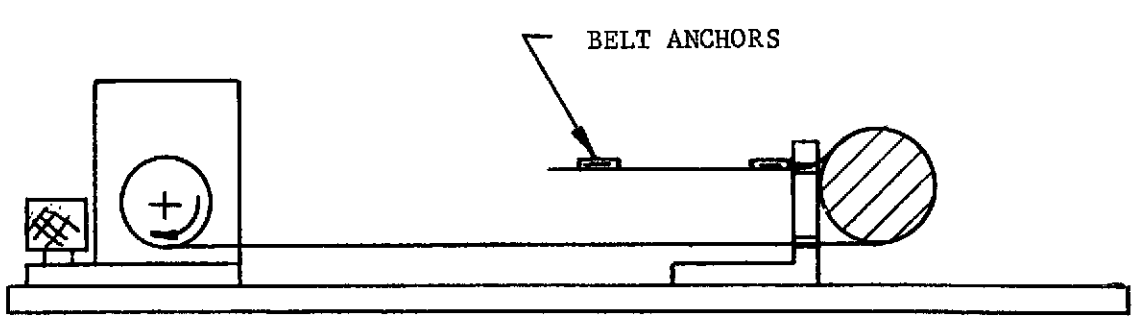


FIGURE III-9 UNIVERSAL TIE-DOWN DEVICE



TIE DOWN OF LARGE OBJECTS





TIE DOWN OF SMALL OBJECTS

FIGURE III-10 TIE-DOWN TECHNIQUES

IV. STRESS AND DYNAMICS ANALYSIS

A. DYNAMICS AND LOADS

Dynamics and stress analyses were conducted to determine preliminary design load factors for the "Universal Stowage Module". Because there are an infinite number of stowage configurations possible, and because methods of stowing items in the modules are in the conceptual stage, the approach summarized here was followed to develop a set of general design curves.

1. Assumptions

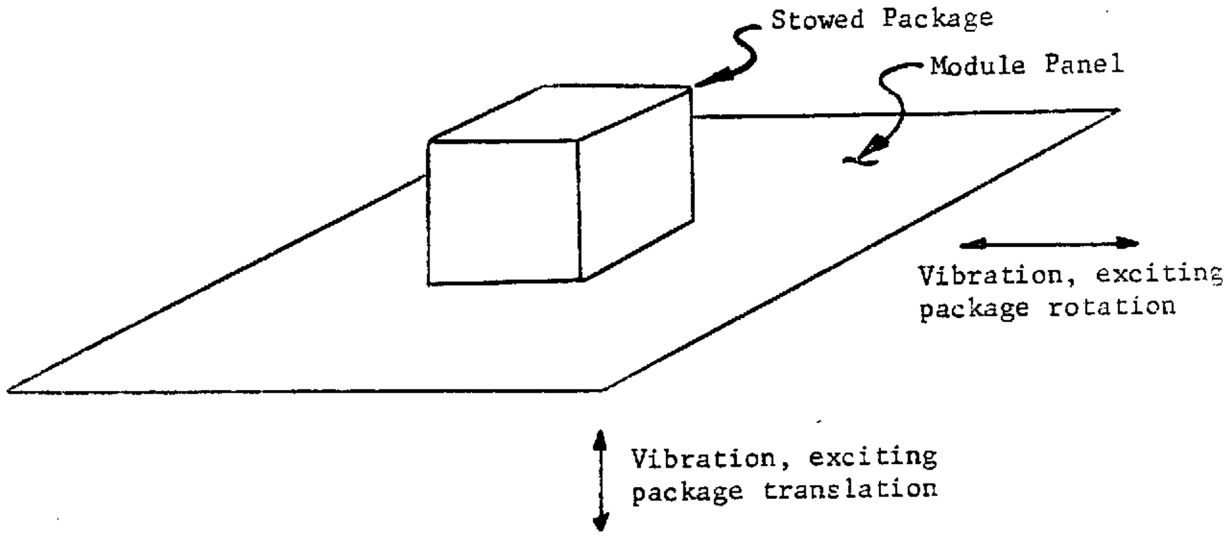
Vibration and response analyses conducted were limited to the following conditions and assumptions.

a. Each stowed item was assumed to be mounted to a single wall panel, with only one item to a panel. No internal partitioning or support structure was considered.

b. The mass of an item stowed in the module was assumed to be either concentrated at a point or in a package of cubic shape of uniform density. Assuming that the mass was concentrated at a point resulted in maximum loading. Though this condition is unrealistic, it represents a limiting case for a very dense item of small volume. The cubic package was assumed to have a density of 416 kilograms per cubic meter (26.0 lbs/cubic foot) which represents the maximum package density expected.

c. Each package was assumed to be centered on a module panel. The load from a point mass acts at the center of the panel and the load from a finite mass acts at the four corners of the package. No unsymmetric panel loading conditions were evaluated.

d. In the vibration analyses, coupling between translation and rotation of a package was not considered. The frequency equation used was derived by the Rayleigh method assuming the panel edges to be simply supported. The following diagrams illustrate the vibration mode shapes assumed for calculating preliminary design load factors.



Actual panel boundary conditions are somewhere between simply supported and fixed but the Rayleigh method usually results in frequencies higher than actual; therefore, the assumption of simply supported edges should result in more realistic frequency calculations. It should also be noted that response in higher vibration modes has been neglected for this study.

2. Results

The results of the study are summarized in Tables IV-1 through IV-3 and Figures IV-1 through IV-3. Tables IV-1 through IV-3 show fundamental frequencies calculated for some specific panel loadings with the corresponding response to random vibration and vehicle dynamics. Maximum acceleration of the package center of gravity is shown along with deflection at the panel center. Panel center deflections were used to calculate "equivalent static load factors" which are plotted versus the panel loading in Figures IV-1 through IV-3. These curves were used by Stress group personnel to check the module basic structure and support bracketry for various stowage configurations.

For a particular stowage configuration being evaluated, an equivalent static load can be obtained for each package from the appropriate curve-translation when the package is being excited perpendicular to the panel and rotation when the package is being excited parallel to the panel, as shown on the following illustration.

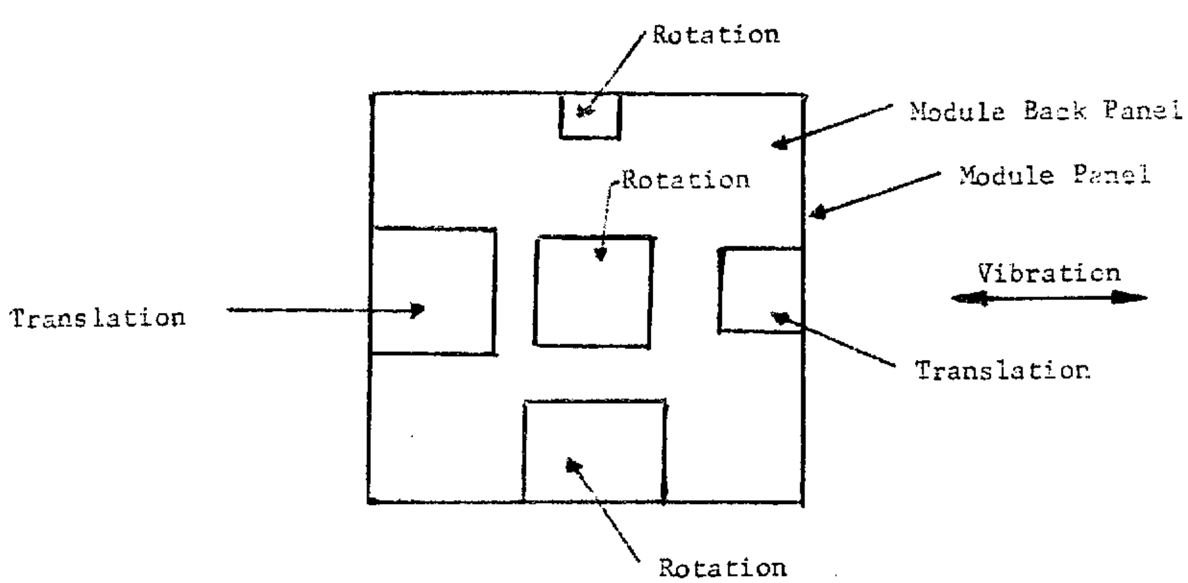


Table IV-1 Cubic Mass at Center of Panel
Translation Perpendicular to Panel

Q = 25.

Load Size, Cube (inches per side)	W (lbs)	$I_{c.g.}$ ($lb\text{-}in^2$)	f (Hz)	Vehicle Dynamics: Accel. at Package c.g. (g)	Vehicle Dynamics: Deflection at Panel Center (inch)	Random Vibration: 2.24σ Accel. of Package (g)	Random Vibration: 2.24σ Defl. at Panel Center (inch)
8.	7.70	82.1	68.0	25.2	0.1103	65.5	0.1755
10.	15.05	251.	56.3	90.0	0.396	45.8	0.207
12.	26.0	623.	52.1	90.0	0.566	39.3	0.252
14.	41.3	1350.	56.3	90.0	0.654	45.8	0.342
16.	61.6	2630.	61.7	90.0	0.775	54.1	0.448
18.	87.7	4740.	81.9	7.56	0.0934	94.1	0.706
20.	120.3	8030.	145.7	5.04	0.1399	169.4	0.836

Table IV-2 Cubic Mass at Center of Panel
Rotation on Panel

Q = 25.

				Vehicle Dynamics		Random Vibration	
Load Size, Cube (inches per side)	W (lbs)	$I_{c.g.}$ ($lb\text{-}in^2$)	f (Hz)	Accel. at Package c.g. (g)	Defl. at Center of Half-Panel (inch)	2.24σ Accel. of Package (g)	2.24σ Defl. at Center, Half-Panel (inch)
8.	7.70	82.1	134.	5.04	0.00544	162.2	0.1128
10.	15.05	251.	94.0	6.30	0.00907	121.8	0.1688
12.	26.0	623.	76.8	9.0	0.01908	83.4	0.1844
14.	41.3	1350.	71.3	16.2	0.0551	72.0	0.218
16.	61.6	2630.	75.8	10.8	0.0400	81.0	0.281
18.	87.7	4740.	95.5	6.48	0.0253	128.0	0.420
20.	120.3	8030.	157.1	4.68	0.01943	171.7	0.434

Table IV-3 Concentrated (Point) Mass at Center of Panel
Translation Perpendicular to Panel

Q = 25.

			Vehicle Dynamics		Random Vibration	
W (lbs)	$I_{c.g.}$ ($lb\text{-}in^2$)	f (Hz)	Accel. of Point Mass & Panel Center (g)	Deflection at Panel Center (inch)	2.24σ Accel. of Point Mass & Panel Center (g)	2.24σ Defl. at Panel Center (inch)
0.	-	152.1	3.96	0.0008	173.	0.0725
2.	-	129.1	4.68	0.0033	159.2	0.0937
5.	-	87.6	6.84	0.0083	107.4	0.1377
10.	-	63.8	32.4	0.0773	57.0	0.1378
20.	-	46.0	90.	0.383	30.1	0.1398
40.	-	32.4	90.	0.766	14.9	0.1398
60.	-	26.6	90.	1.15	10.0	0.1386
80.	-	23.1	75.	1.345	7.68	0.1408

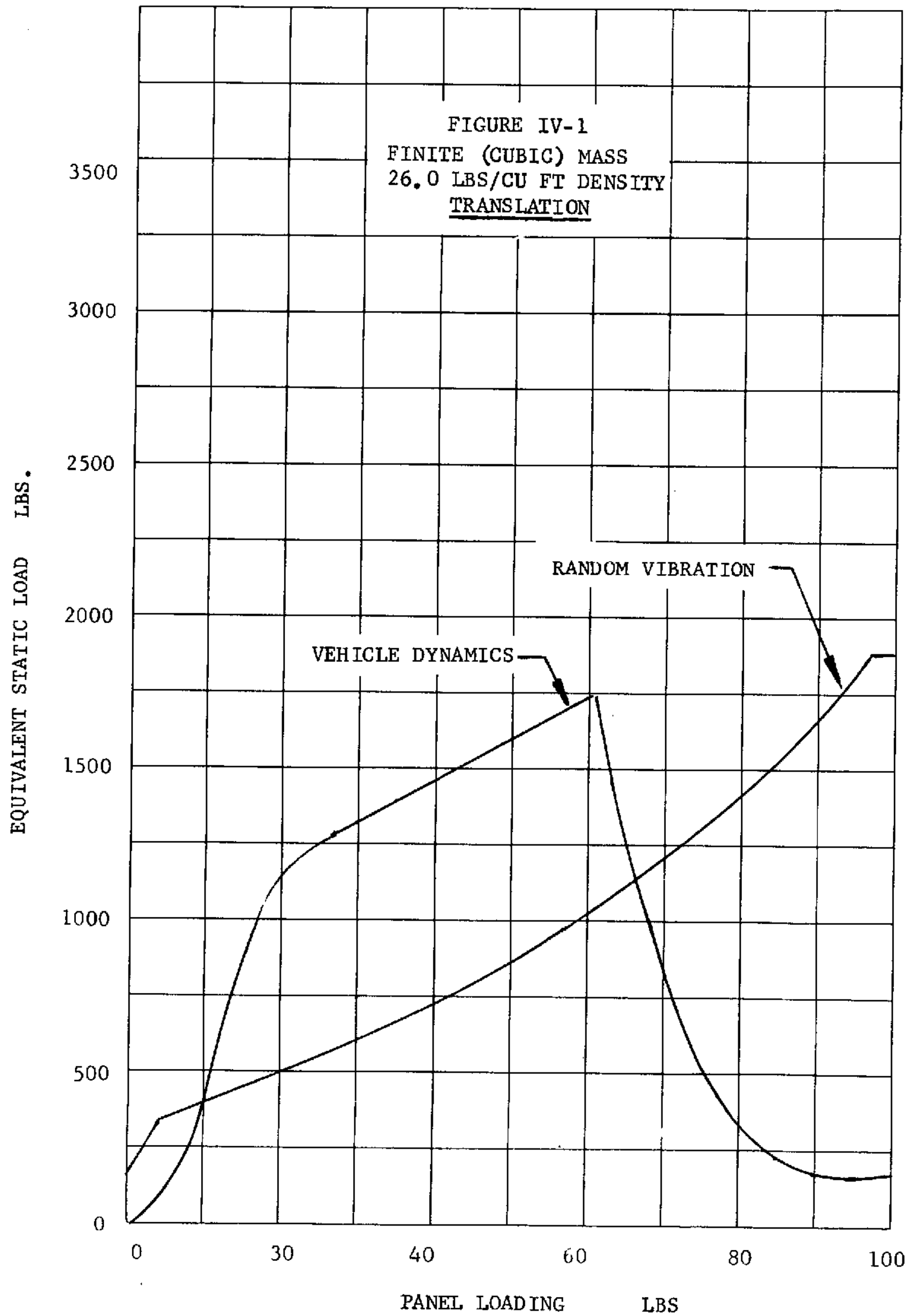


FIGURE IV-1
FINITE (CUBIC) MASS
26.0 LBS/CU FT DENSITY
TRANSLATION
RANDOM VIBRATION
VEHICLE DYNAMICS
3500
3000
2500
2000
1500
1000
500
0
EQUIVALENT STATIC LOAD LBS.
0
30
40
60
80
100
PANEL LOADING LBS

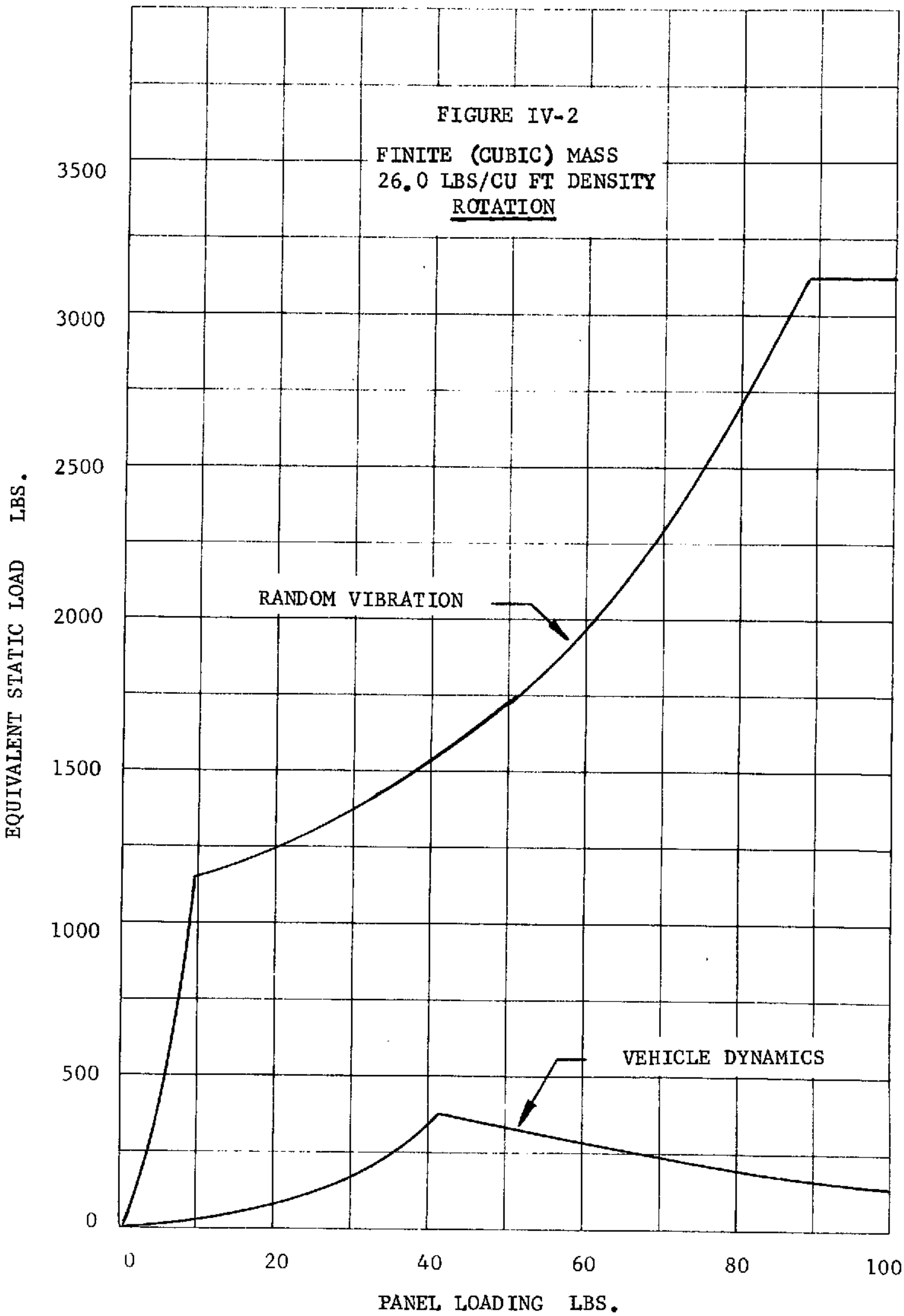


FIGURE IV-2
FINITE (CUBIC) MASS
26.0 LBS/CU FT DENSITY
ROTATION
3500
3000
2500
2000
1500
1000
500
0
EQUIVALENT STATIC LOAD LBS.
RANDOM VIBRATION
VEHICLE DYNAMICS
0
20
40
60
80
100
PANEL LOADING LBS.

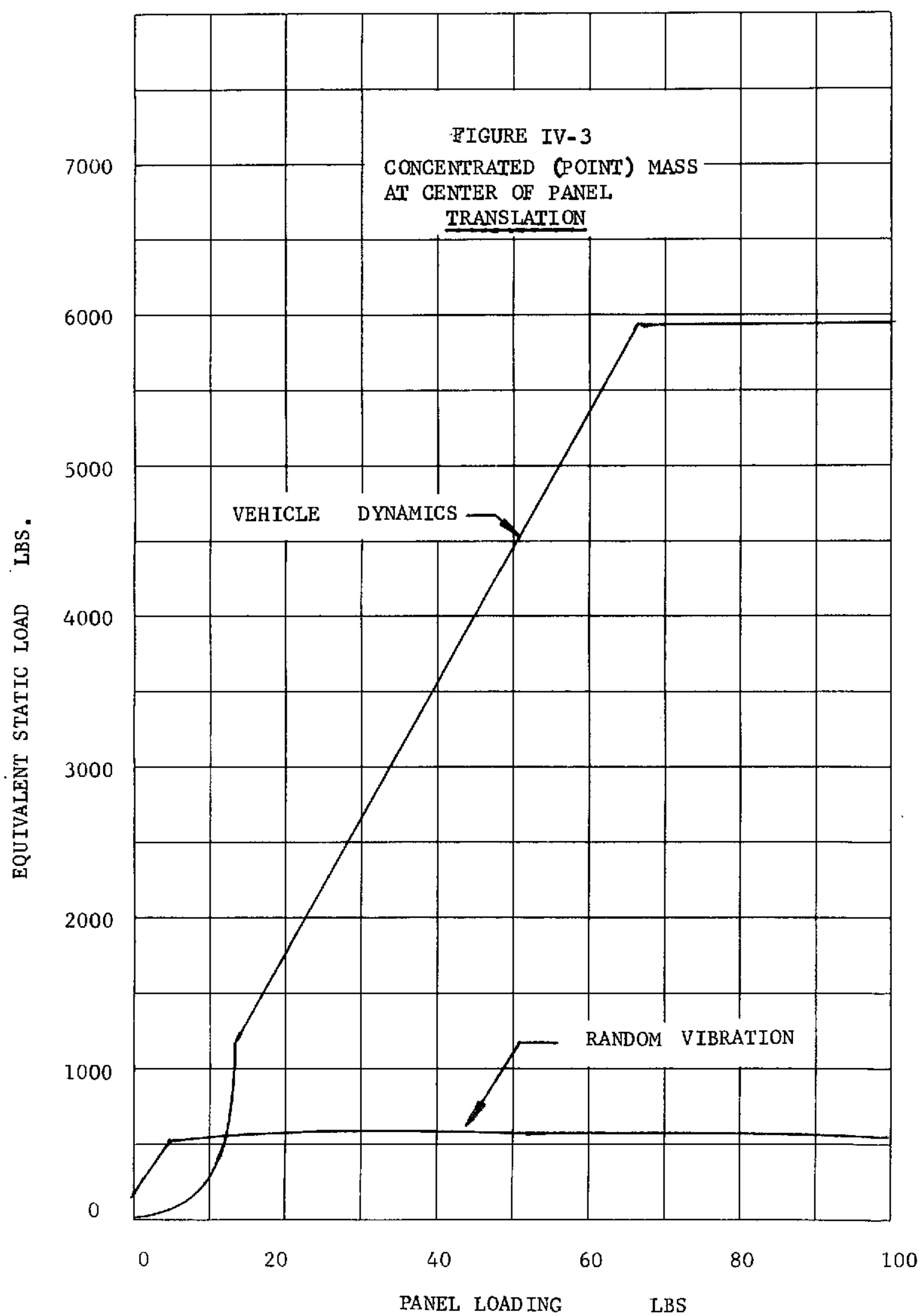


FIGURE IV-3
CONCENTRATED (POINT) MASS
AT CENTER OF PANEL
TRANSLATION
VEHICLE DYNAMICS
RANDOM VIBRATION
7000
6000
5000
4000
3000
2000
1000
0
0
20
40
60
80
100
EQUIVALENT STATIC LOAD LBS.
PANEL LOADING LBS

The equivalent static load was obtained by multiplying the package weight by the equivalent static load factor for each vibration case. Because simplified vibration mode shapes were assumed for this study, phasing between loads cannot be determined. Therefore, loading from each package is added to obtain total loading carried into the module support structure. It should be noted that vehicle dynamics excitation and the high level random vibration spectrum do not occur at the same time in flight; hence, loading from the two conditions should not be added.

3. Conclusions

The dynamics and loads study has established preliminary design load factors which can be used for initial design evaluation and sizing of the module structure. Even though past experience has shown that the results obtained by the methods used for this study provide adequate load factors for initial evaluation of structures, it should not be construed that the results accurately represent frequencies and dynamic loading of the module. The design procedure is actually iterative. As flight hardware is developed, a finite element mathematical model of the module should be developed. This can be used for more accurate loads calculations and also for predictions of environments to be experienced by equipment stowed in the module. Because of the high energy content of the random vibration spectrum as presently defined, fatigue analyses should be conducted; especially if the modules are to be reused for several flights.

B. STRESS ANALYSIS SUMMARY

The Universal Stowage Module structure was analysed using the dynamic loads described in section IVB, and the results of the stress analysis are shown in Table IV-4.

The beaded panel will support a 22.7 kiligram (50 pound) load in the worst case, and the maximum deflection would be 2.4 centimeters (0.951 inches) assuming a concentrated point load in translation. The limiting case is during vehicle dynamics. All loads up to and exceeding 36.3 kilograms (80 pounds) is acceptable in random vibration. In rotation, the panel is also limited at 22.6 kilograms (48 pounds) when considering a cubic shape approximately 38.1 centimeters (15 inches) on a side located in the center of the panel.

These are worst case conditions for the beaded panel. A concentrated load is impossible to duplicate, and if a cubic load of 416 kilograms per cubic meter (26 pounds per cubic feet) is assumed, there is no problem in translation. In rotation, a greater load capability could be realized if the load were either of a lower profile out from the panel, tied into another panel or divider, or placed off center on the panel. In any event, each panel will take 22.6 kilograms (48 pounds) up to a total module load of 36.3 kilograms (80 pounds). If the central divider is tied into a panel, the rigidity of that panel is increased considerably, thus increasing its load capability.

As shown in table IV-4 the remainder of the components and structure in the Universal Stowage Module will meet the design criteria of 36.3 kilograms (80 pounds).

TABLE IV-4 STRESS ANALYSIS SUMMARY

ITEM	LOAD, LBS	FACTOR OF SAFETY	LIMITING LOAD IN MODULE, LBS	REMARKS
Beaded Panel	4500	1.0	50	Concentrated Load (Per Panel) in Translation, Max Deflection at Center is 0.951 Inches.
	1700	1.0	48	Cantilevered Cubic Load (Per Panel) in Rotation, Deflection in One Half Mode is 0.238 Inches.
Front Flange	5444	1.03	80	
Front Lug Bolt	2948	1.80	80	3/8 Inch Diameter Launch Bolt
Rear Support Pin	2948	1.66	80	1/4 Inch Diameter Launch Pin
Central Divider	2872	1.04	80	80 Lbs Equally Distributed on Panel.
Calfax Receptacle	1400 Tensile 2500 Shear	1.89		
Drawer Guide	2872	2.35	80	
Module Door	2800	1.16	80	80 Lbs Bearing Against the Door
Door Latch	2800	3.60	80	
Door Hinge	2800	2.69	80	
Door Hinge Pin	1698	2.46	80	

V. INTERFACE CRITERIA

INSIDE DIMENSIONS	60.96x60.96x60.96 cm	(24" x 24" x 24")
INSIDE DIMENSIONS (DOOR CLOSED)	60.96x60.96x59.53 cm	(24" x 24" x 23.44")
MODULE WEIGHT (EMPTY)	30.6 Kg	(67.5 lbs)
MAXIMUM ENVELOPE DIMENSIONS	72.29H x 68.43W x 62.56 D	(28.46"H x 26.94"W x 24.63"D)
MAXIMUM ALLOWABLE LOAD, CONTENTS	36.29 Kg	(80 lbs)
MAXIMUM ALLOWABLE LOAD, EACH PANEL	21.77 Kg	(48 lbs)
SMALL DRAWER SIZE (INSIDE)	14.20Hx13.44W x 57.45D	(5.59"Hx5.29"Wx22.62"D)
SMALL DRAWER SIZE (WITH FOAM LINER)	11.66Hx10.90Wx54.91D	(4.59"Hx4.29"Wx21.62"D)
LARGE DRAWER (INSIDE)	14.20H x27.99Wx57.45D	(5.59"H x 11.02"Wx22.62"W)

FASTENERS (CALFAX)

RECEPTACLE P/N CA1826-1

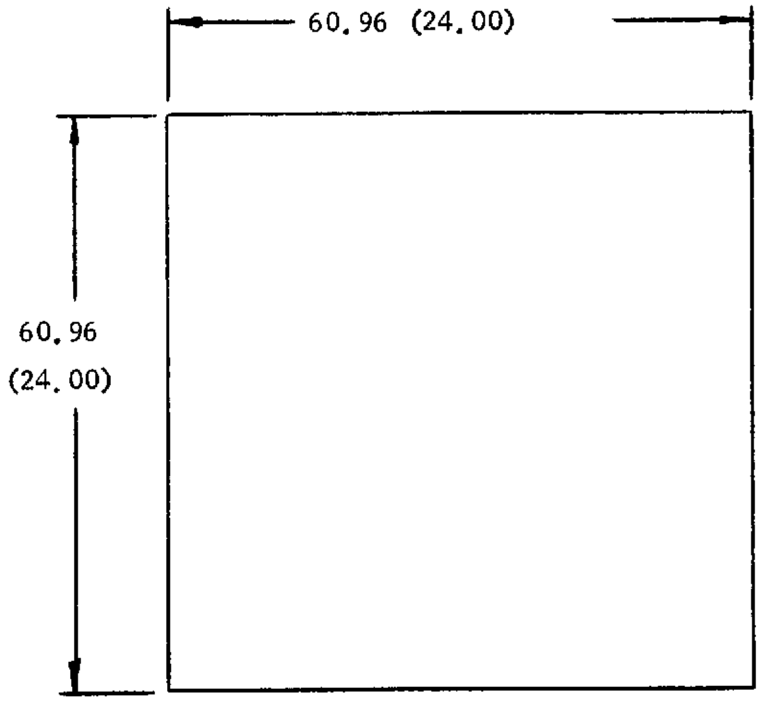
FLUSH HEAD STUD P/N CA1820-1

KNURLED HEAD STUD P/N CA1876-4

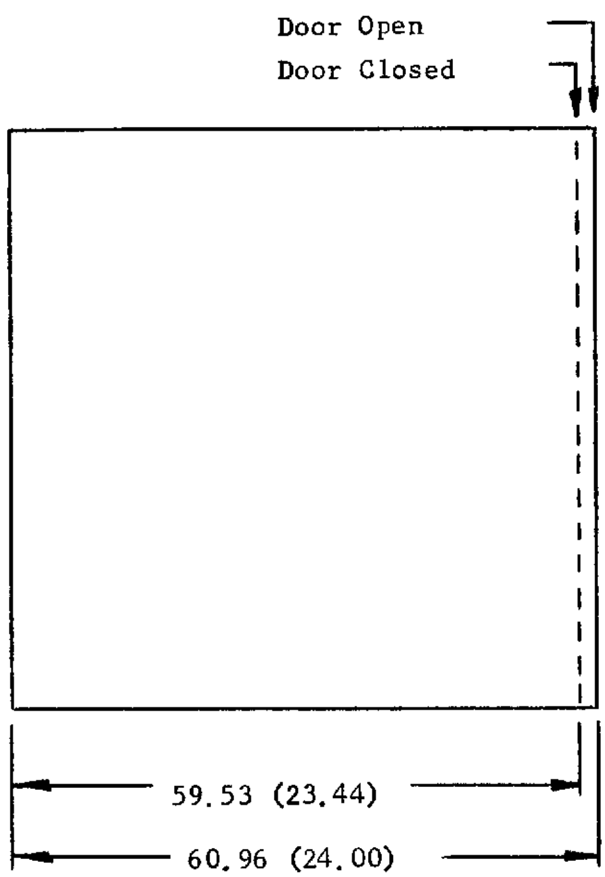
FASTENER PATTERN SEE FIGURE V-4

MAXIMUM TENSILE LOAD (EACH) 635 Kg (1400 lbs)

MAXIMUM SHEAR (EACH) 1134 Kg (2500 lbs)

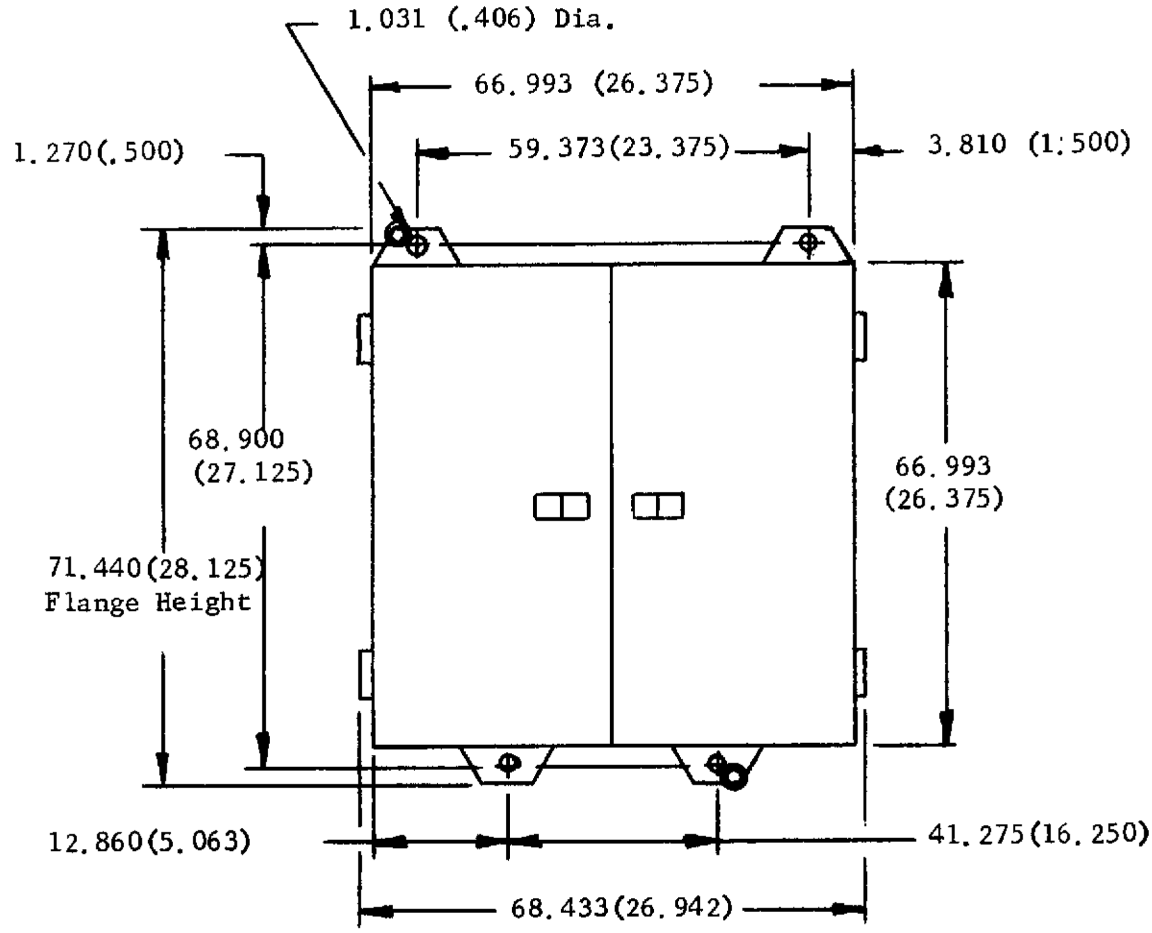


FRONT VIEW

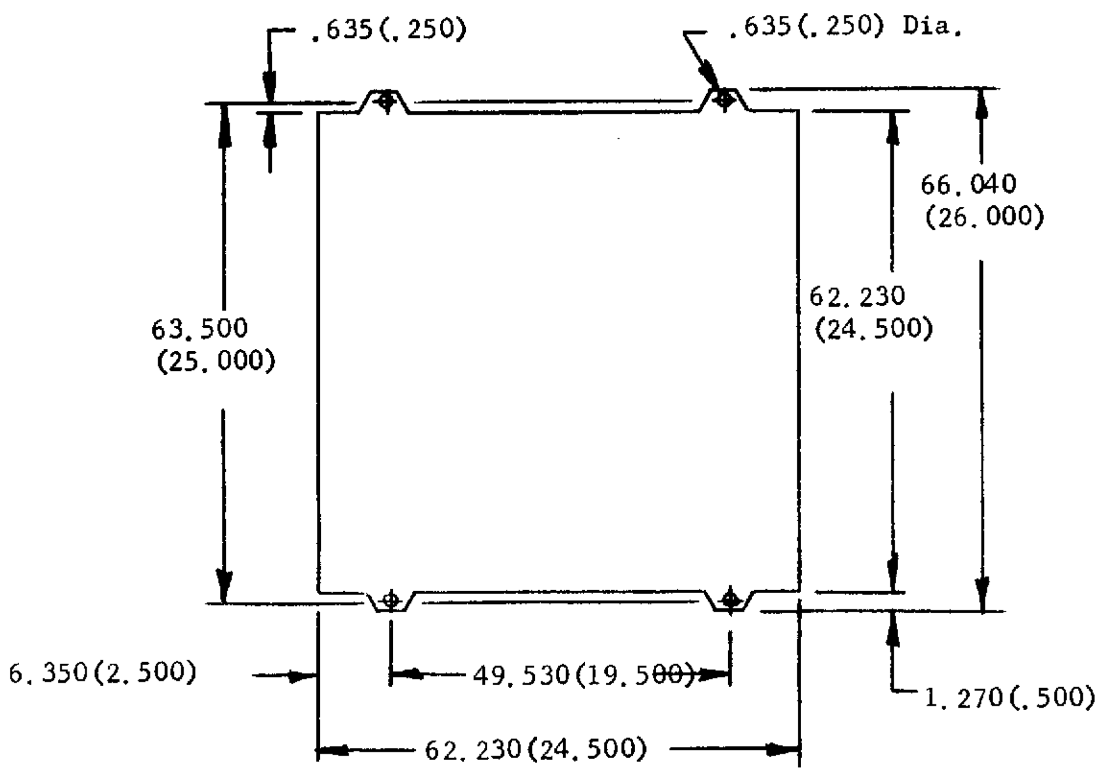


SIDE VIEW

FIGURE V-1 INTERIOR DIMENSIONS

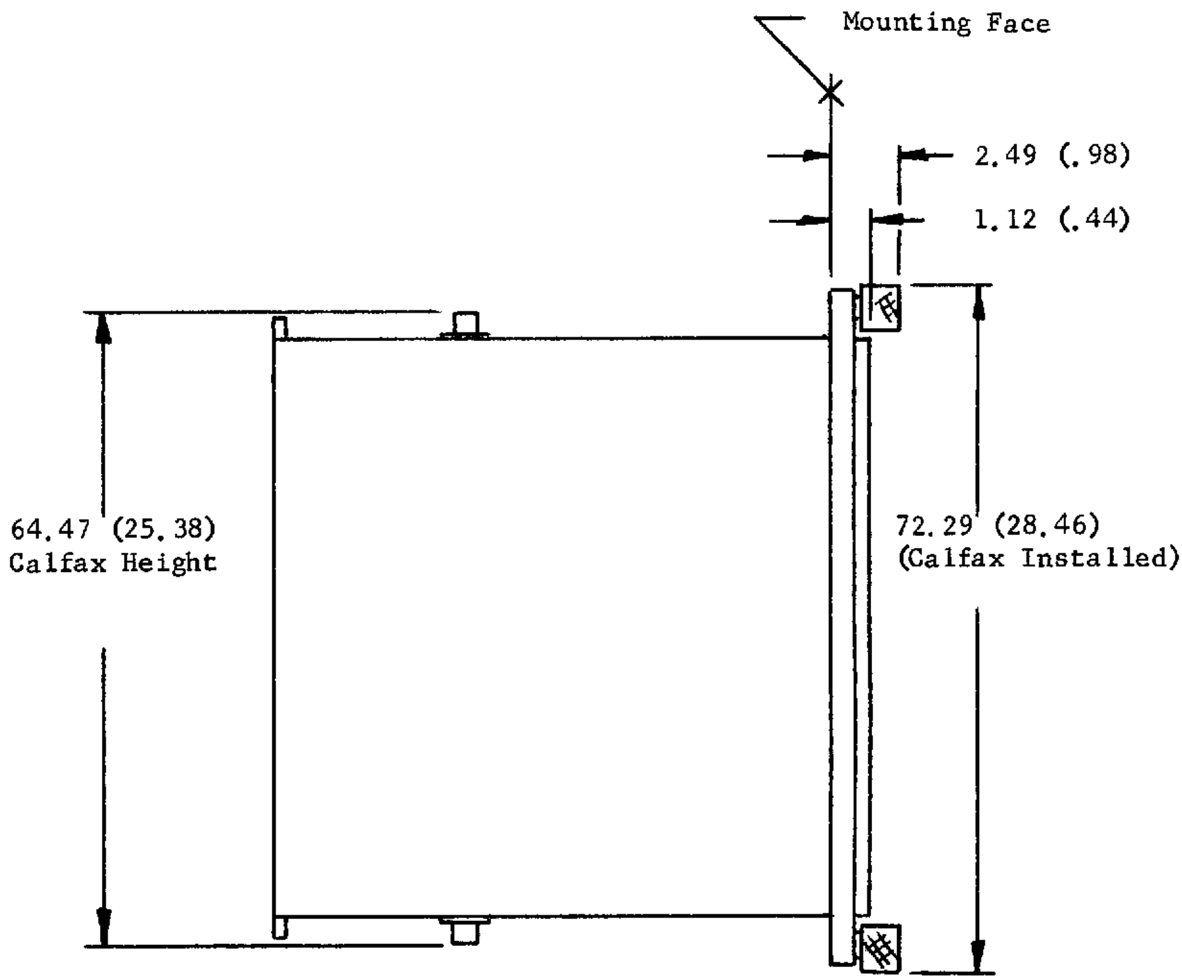


FRONT VIEW



REAR VIEW

FIGURE V-2 MODULE ENVELOPE DIMENSIONS



SIDE VIEW

FIGURE V-3 MODULE ENVELOPE DIMENSIONS

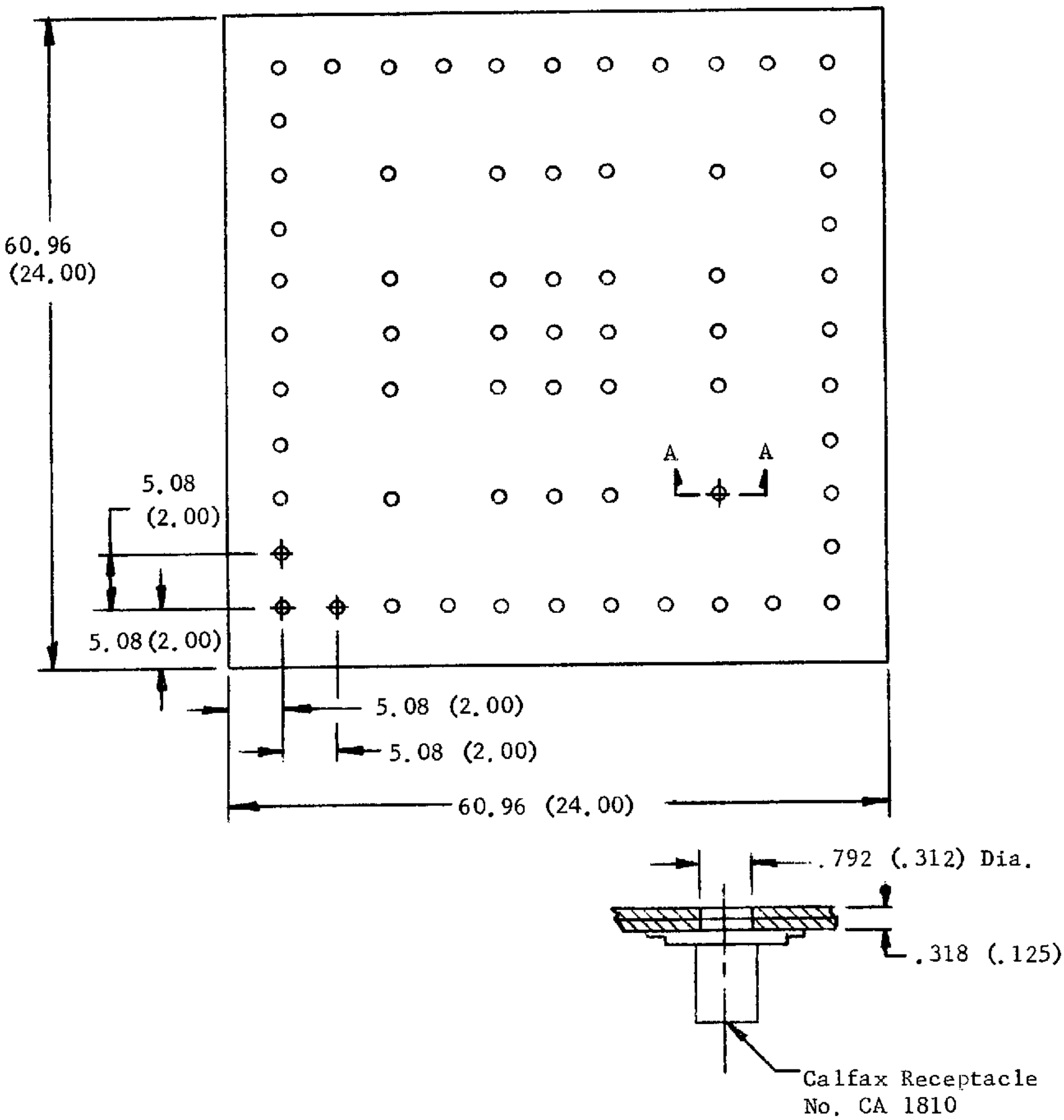


FIGURE V-4 FASTENER PATTERN - WALLS AND BACK

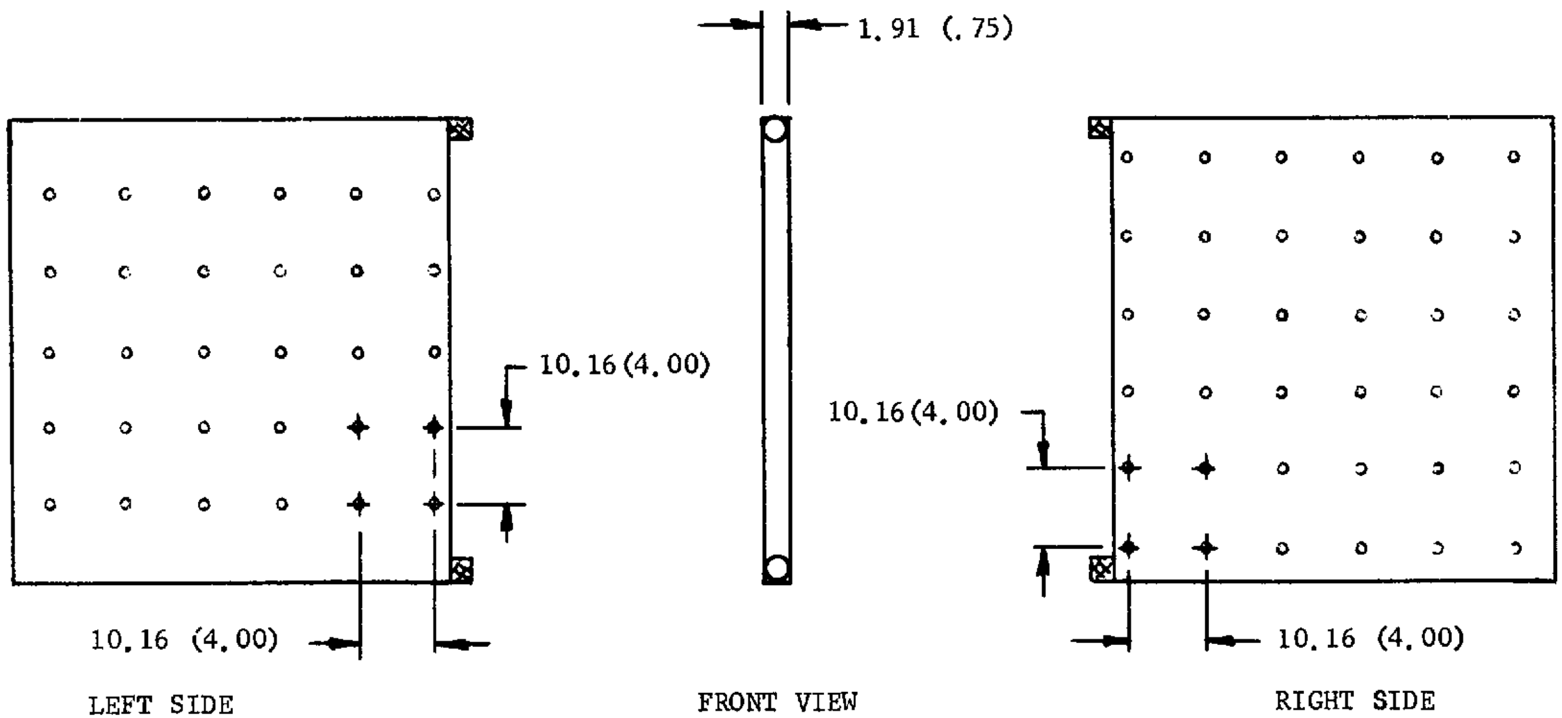


FIGURE V-5 FASTENER PATTERN - CENTRAL DIVIDER

A. ENVIRONMENTAL CRITERIA

Launch and Reentry Loads

Vibration

Sinsusoidal Vehicle Dynamics Environment - The component shall withstand the following environment. Logarithmic sweep at the rate of 3.0 octaves/minute from the low frequency to the high frequency in the thrust direction, 3 Hz to 60 Hz (4.3 octaves).

3 - 7 Hz at 0.43 inch D.A. Disp.
7 - 14 Hz at 1.1 g peak
14 - 25 Hz at 0.11 inch D.A. Disp.
25 - 60 Hz at 3.6 g peak

The component shall withstand the following environment. Logarithmic sweep at the rate of 3.0 octaves/minute from the low frequency to the high frequency in the radial and tangential directions, 2 Hz to 20 Hz (3.3 octaves).

2 - 4 Hz at 0.34 inch D.A. Disp.
4 - 7 Hz 0.28 g peak
7 - 20 Hz 0.08 g peak

Sinusoidal Vibration Evaluation - The component will be subjected to the following excitation. Logarithmic sweep at the rate of 1.0 octave/minute from the low frequency to the high frequency in three mutually perpendicular directions. 20 Hz to 2,000 Hz (6-2/3 octaves).

20 - 100 Hz at 0.002 inches D. A. Disp.
100 - 2000 Hz at 1 g peak

Random Vibration Environment - The component will withstand the specified random vibration for 1.0 minute in each of the three mutually perpendicular directions. The excitation will be applied as one input over the frequency interval from 20 to 2,000 Hz.

20 - 100 Hz at $+9_2$dB/octave
100 - 250 Hz at 1g/Hz
250 - 2000 Hz at -6 dB/octave

Orbiter Payload Load Factors (Steady State)

Structure Load Factors (Max G)

Direction	Steady State	Design Limit	Crash
X-Axis	+3.0, -1.0	± 4.5	-8.0, +1.5
Y-Axis	+1.0	± 2.0	+1.5
Z-Axis	+1.0	± 3.0	+4.5, -2.0

Operating Temperature

The minimum operating temperature will be 50°F.
The maximum operating temperature will be 90°F.

Operating Atmosphere

The atmosphere during operation will be approximately eighty (80) per cent nitrogen and approximately twenty (20) per cent oxygen. The pressure will be 14.7 psia.

Humidity

The operating range of the relative humidity will be thirty (30) per cent minimum and ninety-five (95) per cent maximum.

B. MATERIALS LIST

ITEM	PROTOTYPE MODULE	RECOMMENDED MATERIAL FLIGHT ARTICLE
Beaded Panel	2024-T4 Alum	2024-T4 Alum
Frame	6061-T6 Alum	6061-T6 Alum
Door Assembly	6061-T6 Alum	6061-T6 Alum
Door Lock (Adams Rite P/N 2713-4-120-120)	Pastics and Stainless	Plastics and Stainless
Striker Plates	304 Cres	304 Cres
Calfax Fastener Receptacle	300 Series Cres	300 Series Cres
Calfax Studs	300 Series Cres	300 Series Cres
Nomenclature Card	Nomex & Paper	Nomex Type 410
Rubber Strips, Door	Armaflex Rubber	Mosites
Hinge	2024-T4 Alum.	2024-T4 Alum
Hinge Pin	300 Series Cres	300 Series Cres
Central Divider	2024-T4 Alum.	2024-T4 Alum.
Divider Rails	6061-T6 Alum with Nituff Finish	6061-T6 Alum with Nituff Finish
Pin Alignment Bar	6061-T6 Alum. with Hard-Coat Anodize	6061-T6 Alum with Hard-Coat Anodize
Drawer Partition	6061-T6 Alum.	6061-T6 Alum.
Drawer Divider System	6061-T6 Alum.	6061-T6 Alum
Drawers	6061-T6 Alum	6061-T6 Alum
Drawers Handles	Alum & Butyl Rubber	Alum & Butyl Rubber
Drawer Guide Rail	6061-T6 with Nituff Finish	6061-T6 with Nituff Finish
Drawer Nomenclature Card	Nomex & Paper	Nomex Type 410
Drawer Dividers, Interior	Nylon	Teflon
Drawer, Foam Liner	Arma Flex	Mosites
Drawer, Bubble Pack	Polyethelene	Teflon Film
Drawer, Cloth Liner	Cotton	Nomex S/14 Needle Punch, 10 oz.
Universal Tie-Down, Structure	6061-T6 Alum	6061-T6 Alum
Universal Tie-Down, Ratchet	Steel, Lube	Stainless, Drilube
Universal Tie-Down, Belt	Nylon Webbing	Durette Webbing or Nomex Webbing
Universal Tie-Down, Shaft	Stainless	Stainless